EFFECTS OF NORFOLK HARBOR DEEPENING ON MANAGEMENT OF CRANEY ISLAND DISPOSAL AREA

BY

Donald F. Hayes

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

April 1983

DRAFT

Prepared for U.S. Army Engineer District, Norfolk
Norfolk, VA 23510

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Executive Summary

Three alternatives for using Craney Island disposal area during deepening Norfolk Harbor are evaluated. Storage capacity consumption, operational considerations, construction requirements and management approach are described for each alternative.

Alternative 1 - Alternative 1 considers Craney Island in its present configuration - one large containment area with two spur dikes equally spaced along the east dike extending westward approximately 1/3 of the distance across the containment area.

This alternative requires that the exterior dikes be raised 2 to 4 feet per year during the deepening project depending upon the rate of deepening. The surface elevation will exceed +30.0 ft MLW approximately 75% through the project. Material from suitable deposits within the area can be used for upgrading the dikes thereby slightly increasing the storage capacity. Storage will be required for the remainder of the deepening volume as well as the annual maintenance volume thereafter.

Alternative 2 - Alternative 2 assumes Craney Island is subdivided and managed as recommended in the Craney Island Management Plan (Palermo, Shields, and Hayes 1980) throughout the deepening project.

This alternative requires that the existing spur dikes be extended across the area to form three equally sized subcontainments. The inflow should be rotated annually between the subcontainments. During the two years each subcontainment is inactive, a progressive trenching and dewatering program should be implemented to maximize storage capacity. This alternative will allow all of the maintenance and new work material to be stored within Craney Island without exceeding the +30 ft MLW elevation. However, a deviation from the annual rotation scheme during the last years of the deepening project will be required to accomplish this. The dikes will have to be raised 7 to 12 feet around one subcontainment each year for the first 3 years, then 5-8 ft per year thereafter.

IMPRACTICAL TO IMPOSSIBLE

Alternative 3 - Alternative 3 requires the construction of an expansion to contain all or part of the new work and maintenance volume dredged during the deepening project and requires the development of the existing disposal area as suggested in Alternative 2. This would result in a four subcontainment configuration.

If the expansion is to be used to store <u>all</u> of the material dredged during the deepening project, an area of 850 acres will be required. This will require the dikes for the expansion to be at elev. + 30 MLW by the end of the deepening.

The recommended approach is a combination of Alternatives 2 and 3. The expansion should be filled until its surface elevation matches that of the existing subcontainments in Craney Island. An annual rotation of disposal between the four subcontainments can then be initiated. So the elevation of each subcontaminant will increase at a similar rate, it is suggested that the expansion have a surface area of 750 acres. This approach will allow the material in Craney Island to consolidate and dry for several years before being reused. The expansion will also have the benefit of dewatering and desiccation after its initial filling.

CRANEY ISLANDETTE

The construction requirements for this approach, however, are no less extensive during the deepening than the other alternatives. The expansion dikes must be constructed initially to an elevation of approximately +20 feet MLW. The dikes of one subcontainment must be raised by 7-12 feet each year until the deepening is completed. But, at the end of the deepening, the containment facility should still have a storage life of 10 to 20 more years for maintenance dredging.

WILL BE VERY, VERY EXPENSIVE (POLITICAL) ?

Preface

This report was prepared by the Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), under reimbursable order CA-82-3008. The report was written by Mr. Donald F. Hayes during the period January 1982 to March 1983. The work was accomplished by Mr. Hayes under the direct supervision of Mr. Michael R. Palermo, Chief, Water Resources Engineering Group, and under the general supervision of Mr. A. J. Green, Chief, Environmental Engineering Division, and Dr. John Harrison, Chief, Environmental Laboratory.

The Commander and Director of WES during the study was COL Tilford C. Creel. Technical Director of WES was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	0.4046873	hectares
cubic feet per hour	0.02831685	cubic metres per hour
cubic feet per second	0.02831685	cubic metres per second
cubic feet per second per foot	0.0929	cubic metres per second per metre
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
feet per hour	0.0000847	metres per second
feet per second	0.3048	metres per second
gallons (U. S. liquid)	0.003785412	cubic metres
horsepower (electric)	746.00	watts
inches	0.0254	metres
miles (U. S. statute)	1609.347	metres
pints (U. S. liquid)	0.0004731765	cubic metres
pounds (force) per square inch	6894.757	pascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per square foot	4.882428	kilograms per square metre
pounds (mass) per hour per square foot	0.0013552	kilograms per second per square metre
square feet	0.09290304	square metres
square inches per day	0.00064516	square metres per day
square inches per pound (mass)	0.00142	square metres per kilogram
tons (short) per square foot	9765.1743	kilograms per square metre

PART I: MANAGEMENT ALTERNATIVES

Introduction

Background

1. The accelerating world demand for coal is creating considerable economic pressure for the United States to improve its coal export facilities. At Hampton Roads, Virginia, our Nation's largest coal port, the number of vessels leaving the port at less than capacity for navigational purposes is continually increasing. This has focussed attention on the need to deepen the channels for improved use of deep draft vessels in Norfolk Harbor. Without improvement, this need will intensify and result in greater economic losses.

2. Proposed improvements to the navigation channel in Norfolk Harbor include deepening the service channels, anchorage areas and the Thimble Shoal Channel to elevation -55 feet MLW, the construction of a protective cover for the Thimble Shoal Tunnel, removal of several wrecks located near the shipping lanes, and deepening the access channel into the ocean. The entire project will take place over a 4 to 8 year period depending upon appropriations. The service channels and anchorage areas to be deepened in Hampton Roads are shown in Figure 1.

3. Of the approximately 67.4 million cubic yards of sediment expected to be removed during the total improvement project, approximately 29.1 million cubic yards will be placed in Craney Island. This portion of the project is expected to span over the entire project life. The remaining 38.3 million cubic yards will be placed in an ocean disposal site except for the coarse fraction which will be utilized for beach reclamation.

CAN THESE AMOUNTS BE CHANGED?
(RATIOS)

Objectives of study

4. The objective of this study was to evaluate the impact of the deepening work on the Craney Island Disposal Area and implementation of the Craney Island Management Plan (CIMP) (Palermo, Shields and Hayes 1981). Evaluations of effluent water quality* and its relationship to allowable inflow rate are discussed in Part III. Storage capacity and related topics are addressed in detail in Part IV.

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* Water quality as used throughout this report refers only to suspended solids concentration.

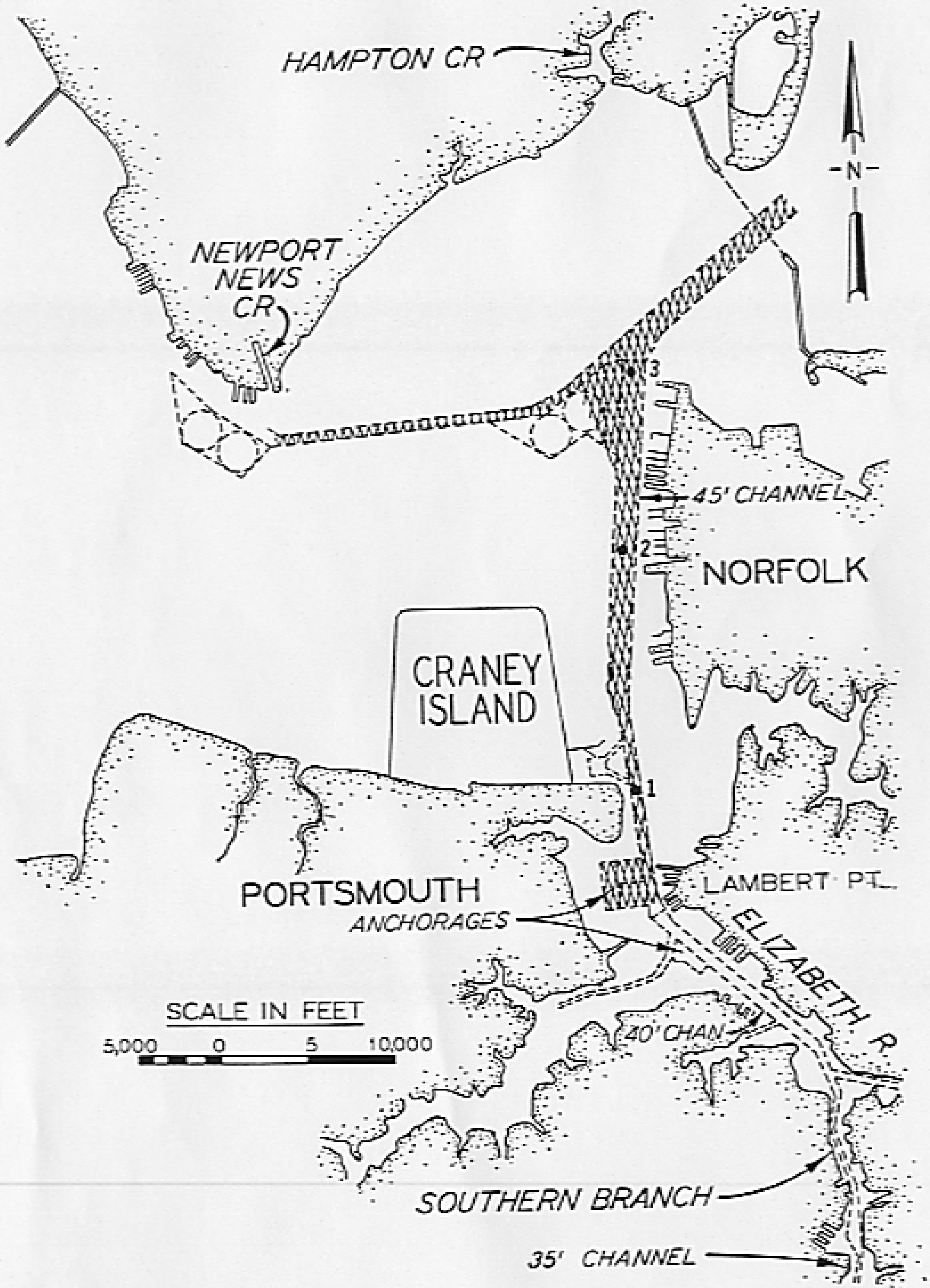

Figure 1: Channel areas to be deepened and new work sampling locations.

5. Three alternatives are compared for disposal into Craney Island. The first assumes that the Craney Island site will be utilized in its present configuration as one large area of 2250 acres. The second assumes the area will be divided into three subcontainments of 750 acres each as recommended in the Craney Island Management Plan (CIMP). The third disposal alternative assumes expansion of Craney Island, forming an additional subcontainment along the west dike. The proposed expansion could be used to contain all the material dredged during the deepening work. If additional storage capacity remained, the expansion could then be utilized as an additional subcontainment for maintenance disposal and used in an annual rotation scheme along with the three subcontainments as suggested in the CIMP.

Relation of study to
Craney Island Management Plan

6. This study is very similar in nature to the CIMP. It includes comparable data collection, laboratory testing, and data analysis techniques. In cases where it is applicable, the data collected for the CIMP have been used. Specific guidance used in this report is documented in the Dredged Material Research Program (DMRP) technical reports (Palermo, et al. 1978, Haliburton, et al. 1978) and related verification studies conducted at the U. S. Army Engineer Waterways Experiment Station (WES).

Report organization

7. A brief discussion of the three alternatives evaluated and the approach recommended is contained in this part. Supporting information regarding sampling, testing, and data analysis is contained in Parts II-IV and the Appendices.

Description of Alternatives

8. Three management and construction schemes are considered for use in disposing dredged material resulting from the proposed deepening of Norfolk Harbor. Evaluation of each scheme includes the effect on the remaining storage capacity in Craney Island. The feasibility of each alternative must be considered in terms of not only construction costs, but also of the consumption of disposal capacity resources and potential operational difficulties. The individual requirements and potential

benefits of the alternatives are described below. A maximum average disposal area fill elevation of +30 ft MLW is used for comparison purposes. The initial dike elevation for Craney Island will be approximately +20.0 ft MLW if the deepening project begins in early 1984 and +21.5 ft MLW if it begins in early 1986.

Alternative 1: Use Craney
Island in its present configuration

9. This alternative considers the use of Craney Island as the existing large containment area with two spur dikes extending 1/3 to 1/2 of the distance across the site. The area would be used to contain both the new work and regular maintenance dredged material. The present method of operation would continue with ponded water continuously inundating approximately 50% of the total surface area. The inflow point should be rotated occasionally to allow some drying to occur. Weir locations are assumed to be unchanged. Suitable borrow material within the area should be used for dike raising during the project to increase the storage capacity as much as possible. Figure 2 shows the dike raising requirements for this alternative. The storage capacity of Craney Island will be exhausted (surface elevation of +30 feet MLW exceeded) before the deepening project is completed if this alternative is implemented.

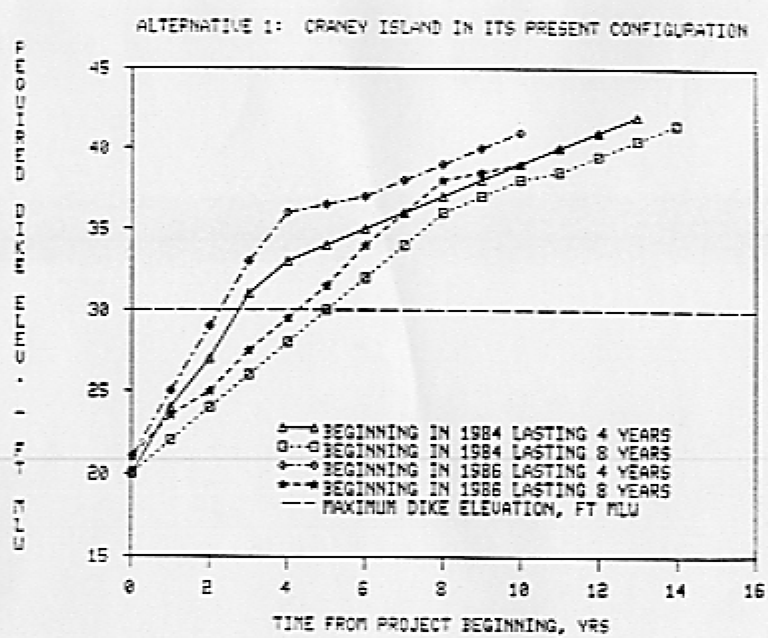

Figure 2. Dike raising requirements for Alternative 1.

Alternative 2: Implement
Craney Island Management Plan

10. Alternative 2 considers Craney Island subdivided into 3 equally sized subcontainments as recommended in the Craney Island Management Plan (CIMP) (Palermo, Shields, and Hayes 1980). The implementation requirements for this alternative are identical to those summarized in the CIMP. The approach for management, operation, and construction is summarized as follows:

- a. The disposal area should be subdivided, forming three subcontainments, by completing the existing interior dikes.

- b. Retaining dikes should be constructed along alignments at a bench distance of approximately 750 ft to allow eventual placement of dredged material to el +30 ft. New weirs will also be required.

  HAS CHANGED FOR WEST PERIMETER DIKE.... MAY CHANGE FOR NORTH AND SOUTH PERIMETER DIKES DEPENDING ON ANALYSIS (RESULTS)

- c. Once closure of interior dikes is completed, disposal should be alternated annually between subcontainments, allowing for a 1-year active disposal cycle followed by a 2-year inactive cycle for each respective subcontainment.

- d. Operation of the active subcontainment will require a ponding depth of 2 to 3 ft, depending on inflow rate. Inflow points should be limited to the east side of the subcontainment.

- e. Management of inactive subcontainments should emphasize removal of surface water, prevention of ponding, and construction of surface drainage systems to efficiently remove precipitation and dewater the fine-grained dredged material. Surface drainage should be accomplished by constructing periphery trenches adjacent to the subcontainment dikes using draglines and interior trenches using amphibious rotary trenchers or other suitable equipment.

- f. Dikes should be continuously upgraded as conditions allow, primarily using material excavated from periphery trenches and accumulated coarse-grained material as required.

The above approach is discussed in detail in the CIMP. Figure 3 shows the requirements for dike construction for this alternative. The storage capacity will be exhausted (assuming a maximum average surface elevation of +30 ft MLW) at the end of the deepening. A modification of the annual rotation scheme may also be required during the last years of the deepening project to retain all of the material in Craney Island.

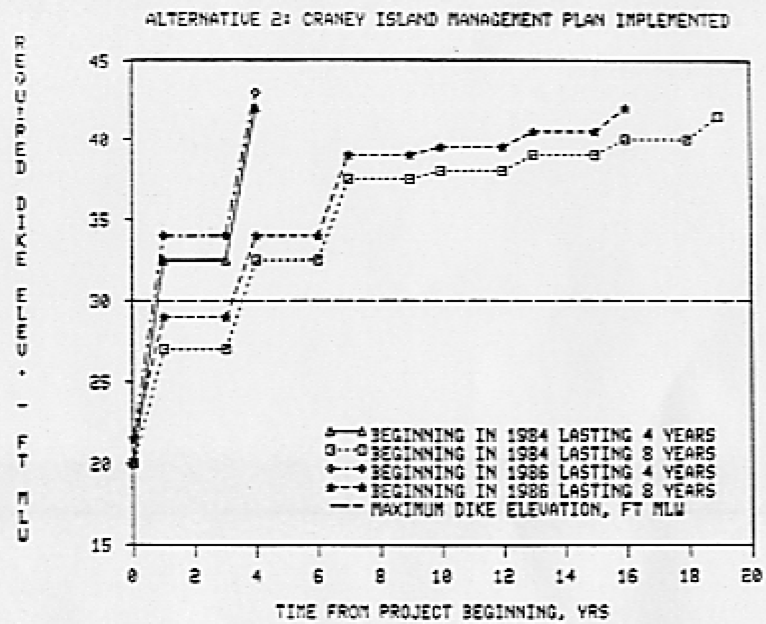

Figure 3. Dike raising requirements for Alternative 2.

Alternative 3: Construct an expansion to Craney Island to hold all new work and maintenance material dredged during the deepening project

11. Alternative 3 considers the implications of constructing an expansion to hold the new work and maintenance material dredged during the deepening project. The expansion would be built along the west dike with a length to width ratio of 2 as shown in Figure 4. During the deepening project, Craney Island would be managed to maximize surface subsidence by removing the surface water and using progressive trenching. The three subcontainments for the existing site should also be completed during this period as recommended in the CIMP. Construction of the expansion would have to be done rapidly to stay ahead of the filling. Some of the material being dredged may be suitable for dike construction, especially if "clay balls" are being formed. Figure 5 shows the requirements for dike construction for a 750 acre expansion and Craney Island. This alternative allows the service life of Craney Island to be slightly increased over that originally projected in the CIMP, i.e. a usable disposal life of over 16 years after the deepening is completed. An 850 acre expansion is required to contain all of the new work material without utilizing the existing containment areas.

$850_{AC} (43560 \frac{FT^2}{AC})\ 0.1111 \frac{Yd^2}{FT^2} = 4,114,000\ SY$

$\frac{29,100,000\ CY}{4,114,000\ SY} = 7.034\ Yds = 21.22\ ft = H$

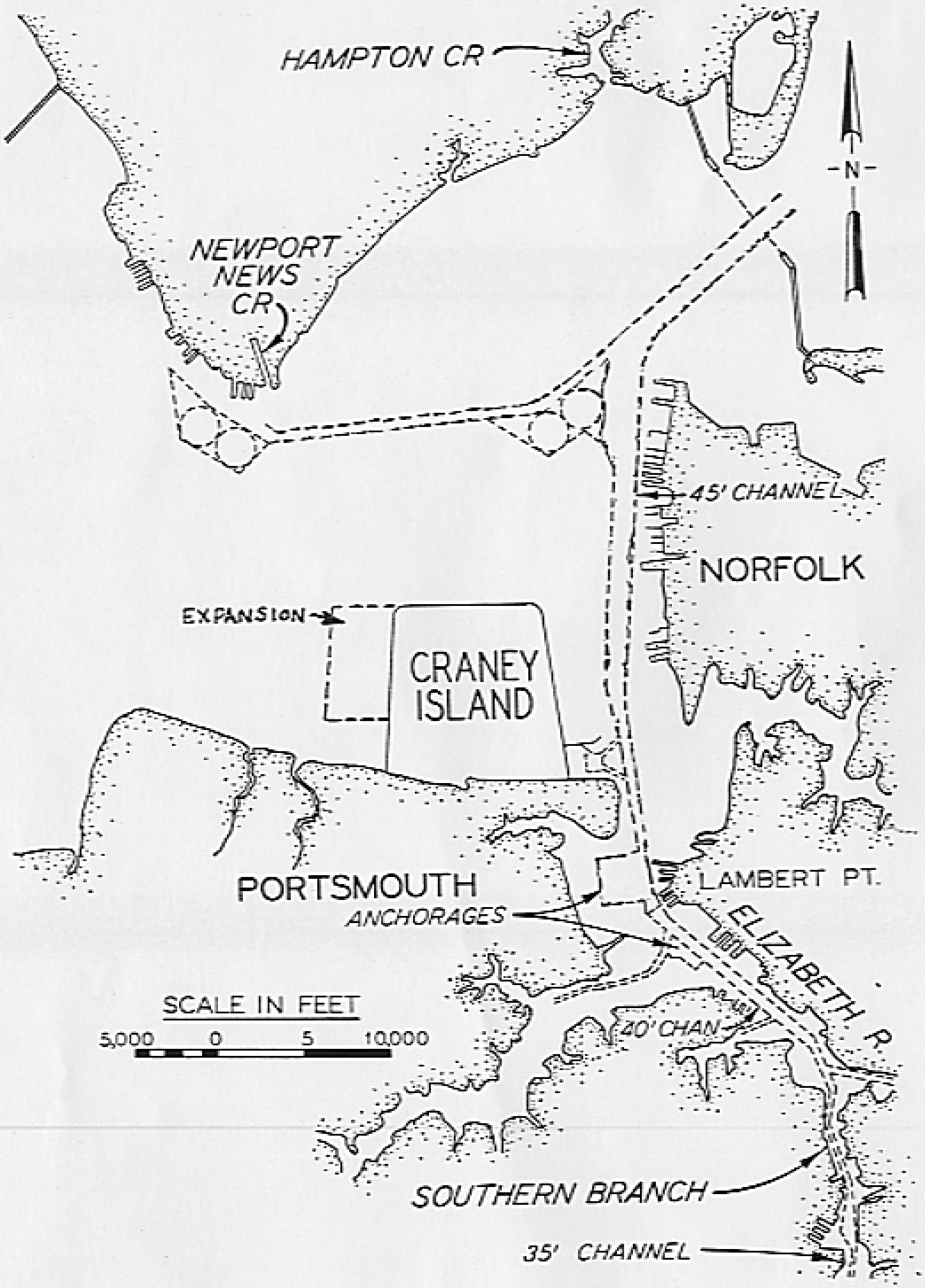

Figure 4: Suggested location and approximate scaled dimensions for expansion.

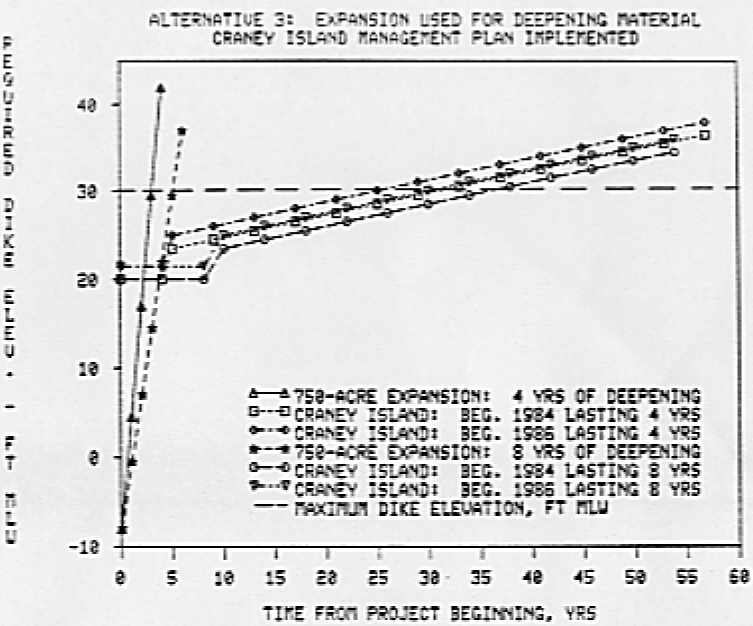

Figure 5. Dike raising requirements for Alternative 3.

Comparison of Alternatives

12. Expansion of Craney Island is the only management alternative evaluated in this report that is considered operationally practical. The other two alternatives would result in either exhaustion of disposal capacity before completion of harbor deepening or shortly thereafter. Alternative 1 would result in the filling of Craney Island to capacity before the harbor deepening is completed. The alternative involving implementation of the CIMP is technically feasible but would exhaust all storage capacity in Craney Island and a new disposal alternative would be required to meet the annual maintenance disposal requirements.

Recommended Construction and Management Scheme

13. A modification of Alternative 3 is recommended, involving the construction of a new cell with a surface area of 750 acres. This cell should be used for disposal of all maintenance and new work material until the surface elevation is equivalent to that of the existing portion of

Craney Island. During the deepening, the spur dikes in the existing portion of Craney Island should be extended to subdivide it into 3 areas of 750 acres each (subcontainments 1 through 3). When the elevation in the new cell (subcontainment 4) reaches an elevation equivalent to subcontainments 1 through 3, disposal can then be rotated annually between the subcontainments. This management scheme allows each cell to dry for 3 years between active disposal periods, and allows the surface elevation of each cell to increase at a similar rate. The dike construction requirements for the recommended approach are shown in Figure 6. Weir structures 75 feet long should be located in each corner of one end of the subcontainments, as recommended in the CIMP.

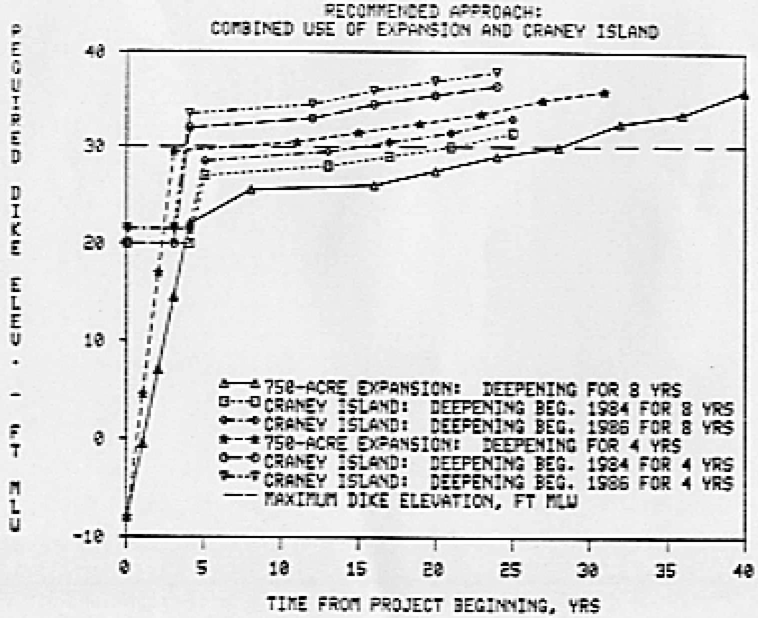

Figure 6. Dike raising requirements for the recommended approach.

Operation and Management Guidelines

14. Guidelines similar to those recommended in the CIMP are required for operation and management of the four subcontainment disposal areas. The guidelines may be categorized as pertaining to general concept

of operation and management, construction requirements, operation during active cycles, management during inactive cycles, dewatering activities, monitoring material reclamation, and landscaping.

General concept of
operation and management

15. Guideline 1: Sequence disposal operations between subcontainments on an annual basis. Upon completion of the expansion and interior dikes, the disposal area will be operated by sequencing disposal between the four subcontainments on an annual basis. Each subcontainment will be operated and managed according to a 1-year active cycle (ongoing disposal operations), followed by a 3-year inactive cycle (management to promote drying). At any given time, one subcontainment will be operated to accommodate disposal operations (active cycle) while the remaining three subcontainments will be managed to promote drying (inactive cycle).

16. Guideline 2: Pond water only during active cycles. During active cycles, ponded water will be maintained within the subcontainment to promote effective sedimentation, thereby ensuring acceptable water quality of effluent (see Guideline 8).

17. Guideline 3: Prevent ponding during inactive cycles. Surface water will be removed to prevent ponding within the three inactive subcontainments to promote drying and restoration of storage capacity.

Construction requirements

18. Guideline 4: Construct the 750 acre expansion rapidly, initially raising dikes to the same elevation as the west dike of Craney Island. Prior to the deepening, consideration should be given to construction of this new cell. The cell should be at least partially constructed before the deepening begins. Material being dredged from other projects in the harbor as well as material inside Craney Island deemed suitable for use as dike material should be used. As the deepening progresses, dike raising should continue at the most feasible rapid rate until the elevation of Craney Island's west dike is reached.

TIME FACTOR

19. Guideline 5: Upgrade dikes during inactive cycles. During available 3-year inactive cycles, subcontainment dikes should undergo rehabilitation and upgrading to prepare for the next active cycle. This process should be accomplished gradually, using dewatered dredged material

available along the dike alignment to the greatest degree possible. Upgrading is best accomplished during the process of periphery trenching (Guideline 15).

20. Guideline 6: Perform necessary preparation of subcontainments. Final inspection of subcontainment dikes and miscellaneous preparation activities should be accomplished immediately prior to initiation of an active cycle. Preparation activities should include removal of vegetation which might cause short-circuiting in a ponded condition, boarding the weir to maintain the required minimum depth of ponding, and placement of any desired instrumentation for monitoring activities.

21. Guideline 7: Complete the interior dikes of Craney Island and replace weir structures with 150-foot-long corner weirs as recommended in CIMP prior to filling the expansion to the surface elevation of Craney Island. As the new cell fills, construction on Craney Island should continue. The interior dikes as recommended in the CIMP should be established before the fill elevation of the fourth subcontainment reaches that existing in subcontainments 1-3. The existing weir structures should be replaced with ?check dimensions 150-foot-long weir structures located in the westerly corners of each subcontainment.

Operation during active cycles

22. Guideline 8: Maintain ponding depth along western dike as a function of inflow rate. Ponded depth of water along the western dike should be maintained as a function of inflow rate during the entire active cycle. Since disposal operations occur on a year-round basis, a pond will be maintained in the active subcontainment a majority of the time. The guide curve in Figure 7 should be used to determine required ponding depth along the west dike for a given inflow rate. The guide curve is designed to provide required ponded surface area for the corresponding ponded depth, considering average surface slope within the disposal area; therefore, local depressions caused by trenching or erosion should not be considered when setting the ponding depth. If inflow is discontinued for significant periods, the pond should be drawn down in accordance with Guideline 13. A minimum ponding depth of 2 ft is recommended, even though lesser ponding depths may result in sufficient ponded surface areas for settling at low flows. The 2-ft minimum will reduce any tendency to short-circuit and will offset any local variation

in surface topography, allowing flow to reach both weirs. The weir boarding will require periodic adjustment as the dredged material surface rises, so that suitable ponding depth is always maintained. The technical basis for this guideline is found in Part III.

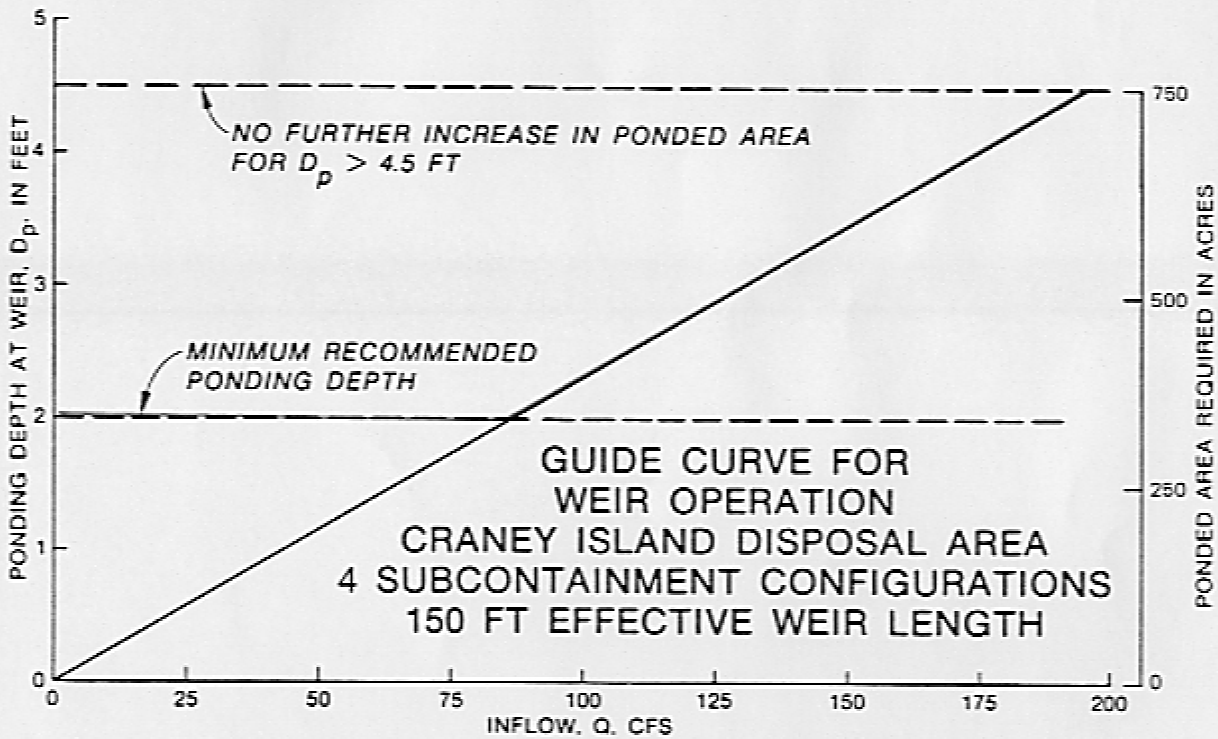

Figure 7. Guide curve for weir operation, 150-ft effective weir length four-subcontainment area configuration

23. Guideline 9: Operate weirs to maintain water quality. Weirs should be operated in accordance with the following general guidelines:

- a. The weir crest elevation should be maintained at the highest feasible elevation to ensure maximum effluent water quality.
- b. Floating debris should be periodically removed from the front of the weir to prevent withdrawal flows at greater depths.
- c. The crest of both weirs in the active subcontainment (assuming that both weirs are operating) should be maintained at the same elevation.
- d. If effluent suspended solids concentrations rise above acceptable limits, the ponding depth at the weir should be increased. If this is not feasible from a dike stability standpoint, the inflow rate must be decreased by operating intermittently or temporarily diverting flow to an inactive subcontainment.

24. Guideline 10: Locate inflow points along the north and east dike. Inflow points should be located along the eastern retaining dike for subcontainments 1-3. Inflow point for subcontainment 4 should be located along the north dike. If two or more dredges are operating simultaneously, the inflow points should be separated as far as practicable to reduce any tendency to short-circuit. Inflow points located adjacent to the retaining or interior dikes will facilitate accumulation of coarse material in areas suitable for later reclamation.

25. Guideline 11: Periodically monitor effluent suspended solids. Effluent suspended solids should be monitored periodically to ensure that water quality is being maintained. Indirect indicators of suspended solids concentration, such as visual comparison of effluent samples with samples of known concentration, should be used on a daily basis. Laboratory determination of effluent suspended solids should be performed on a weekly basis if visual inspection indicates need.

26. Guideline 12: Specify inflow point in the contract and alternate between subcontainments on separate contracts. The alternation between subcontainments, or "switchover," should be planned to coincide with initiation of a separate contract item. Points of inflow should be specified in the dredging contracts. The switchover should be planned well in advance based on anticipated duration of contracts and volumes to be dredged unless unusual conditions require a quick change.

Surface water management during inactive cycles

27. Guideline 13: Remove pond following completion of active cycle. Ponded water should be slowly decanted following completion of the active cycle (or if inflow is discontinued for prolonged periods during an active cycle). A row of stoplogs should not be removed until the water level is drawn down to the weir crest and outflow is low. It is desirable to eventually remove stoplogs below the dredged material surface once the material has consolidated and dried sufficiently to prevent flow or excessive erosion. Notched stoplogs may be placed in the final stages to allow slow removal of smaller ponds. This is a critical factor in maximizing surface subsidence due to drying. While the new cell is being filled, this type of management should aid storage capacity enhancement.

28. Guideline 14: Lower weir crest during inactive cycles as required to prevent ponding. The dredged material surface will subside during inactive cycles due to consolidation/desiccation. Weirs must be periodically checked and stoplogs removed to prevent subsequent ponding during inactive cycles.

Dewatering activities

29. Guideline 15: Construct periphery trenches for initial dewatering. Construction of periphery trenches should be initiated as soon as possible during the initial portion of inactive cycles. The periphery trenches should be constructed adjacent to the subcontainment dikes and should lead to the weir structures (Figure 8). Draglines working from the dikes or on mats adjacent to the dikes are probably best suited for constructing the trenches. Material excavated during periphery trenching should be directly placed on the dike to raise the dike section or spread between the dike and trench to dry for later use in dike raising.

30. Guideline 16: Construct interior trenches for additional dewatering. Once periphery trenches are completed, forming a flowpath to outlet weirs, interior trenching to further increase surface drainage efficiency should be initiated. The interior trenches should be constructed in a V-pattern (Figure 9), taking advantage of the surface slope to drain water toward the periphery trenches. Depending on final equipment selection, a crust thickness of 4 to 6 in. is desirable before interior trenches should be initiated. Rotary trenchers or draglines mounted on similar amphibious carriers are recommended for interior trench construction. The final equipment selection should be based on field trials.

Monitoring program

31. Guideline 17: Install desired instrumentation during inactive cycles and monitor as required. Instrumentation such as settlement plates or piezometers should be placed during inactive cycles when access to the site interior is possible. Monitoring of surface subsidence, rates of filling, and groundwater table fluctuations should be accomplished as required to compare field behavior with prior estimates.

HAVE BEEN PLACED.... BUT TO MY KNOWLEDGE HAVE NOT BEEN MONITORED

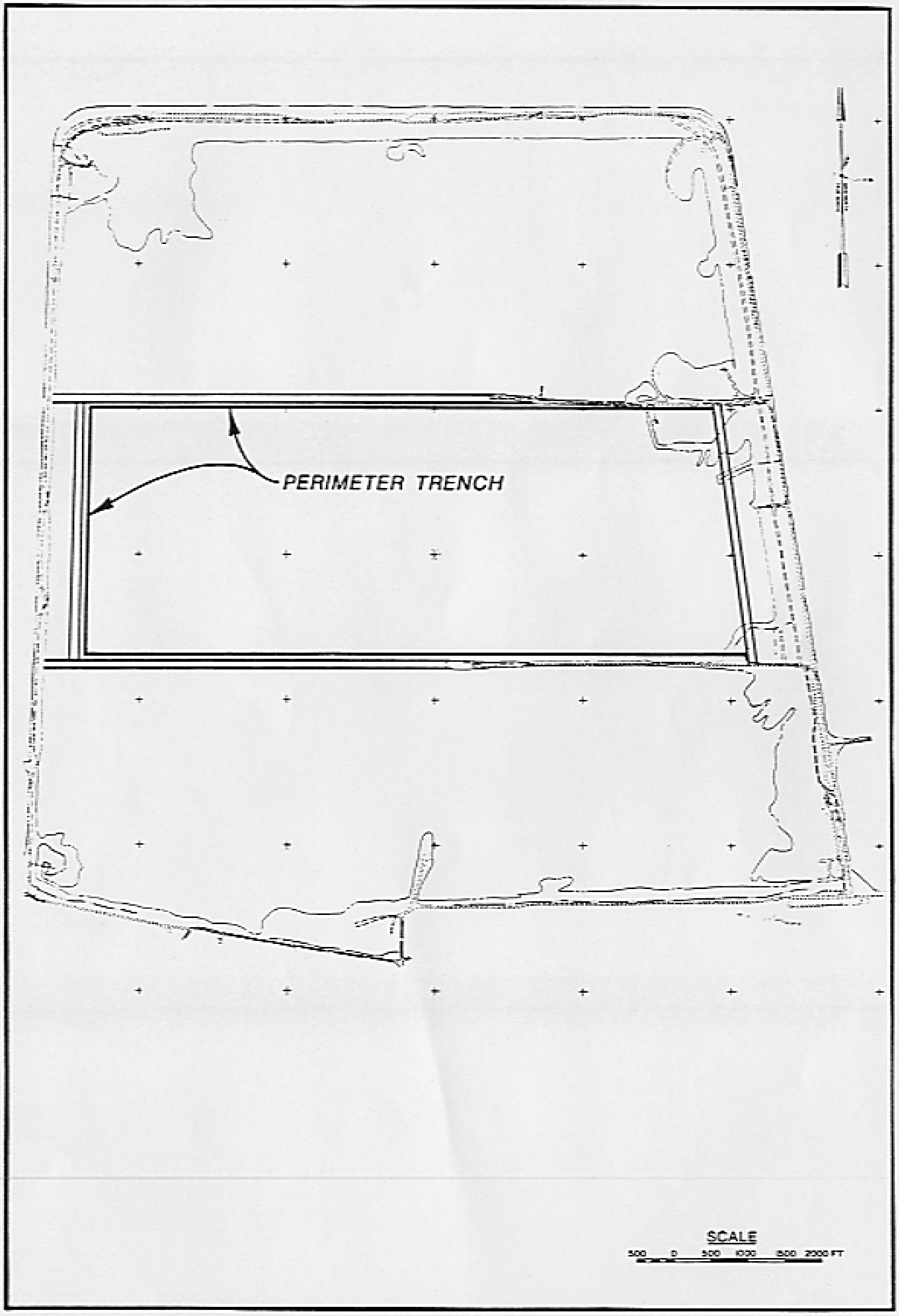

Figure 8. Periphery trench layout for dredged matetial dewatering (from CIMP)

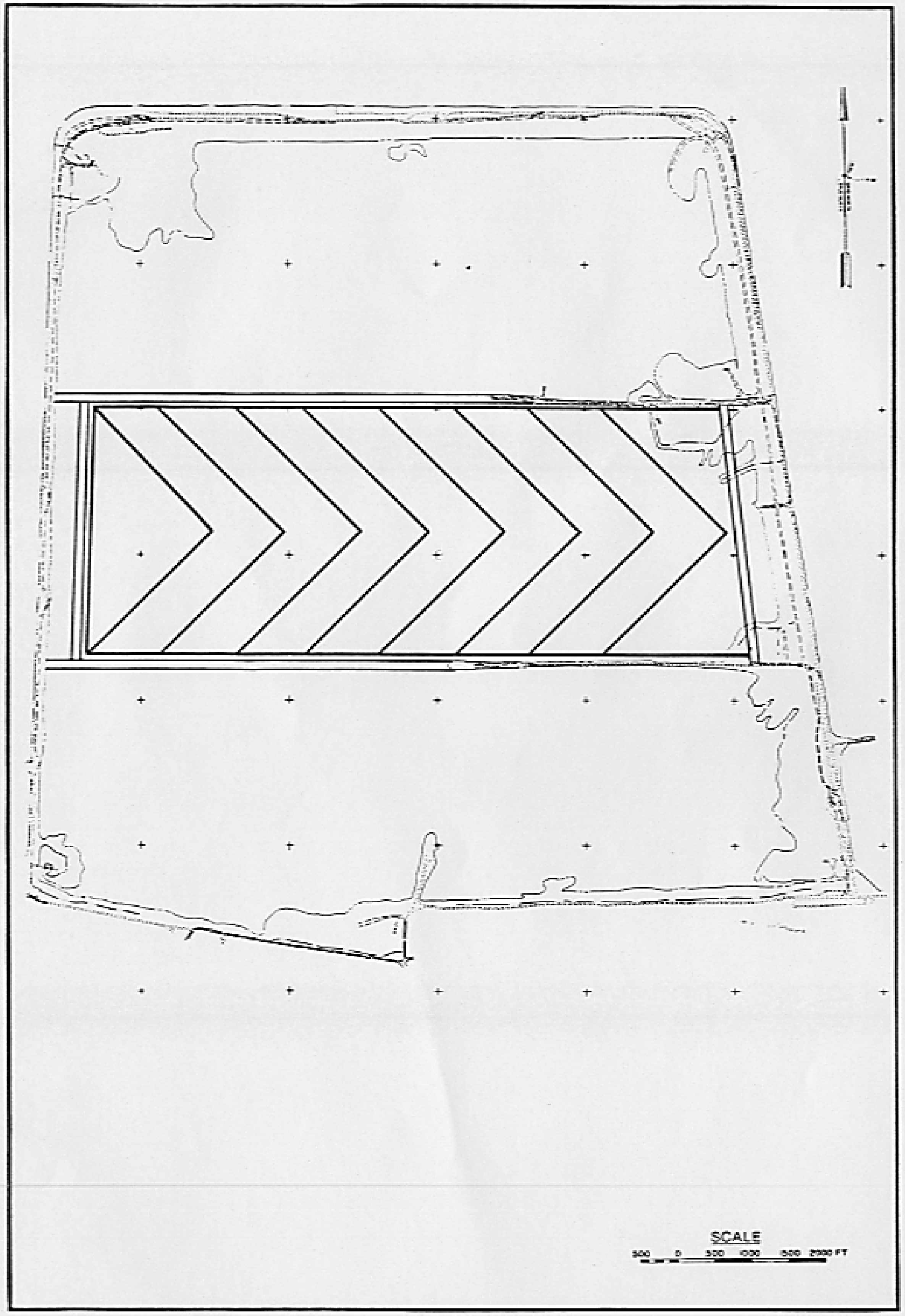

Figure 9. Interior trench layout for dredged material dewatering (from CIMP)

Dredged material reclamation

32. Guideline 18: Reclaim and use coarse-grained material. Reclamation of coarse-grained dredged material from areas coinciding with traditional points of inflow should continue on more or less the same volume basis as at the present time. Techniques now used to reclaim this material seem to be the best suited for this particular site. The areas over which suitable coarse-grained material is located are relatively small in comparison with the overall size of the disposal area. Loading of small quantities by dragline or front-end loader directly into trucks for transport is the most cost-effective approach. For some applications, OK use of scrapers to move large quantities to rehandling points or directly to areas of dike upgrading may be feasible.

33. As the retaining dikes and interior dikes are upgraded, the onsite requirements for coarse-grained material will increase. It may therefore be assumed that a majority of accumulated coarse-grained material will be productively utilized in dike upgrading and maintenance activities. Sale and removal of excess coarse-grained material offsite should continue at approximately the present rate.

Landscaping

34. Guideline 19: Perform desired landscaping activities as retaining dike is upgraded. Landscaping at the entrance gate locations and along the exterior face of the main retaining dikes should be completed as recommended in the CIMP.

PART II: FIELD AND LABORATORY INVESTIGATIONS

35. This part describes field and laboratory investigations conducted for new work material. Similar investigations for maintenance sediment are documented in the CIMP.

Sediment Sampling

36. Samples of new work material were taken at three locations in the project area (Figure 1) by Norfolk District personnel. The samples were taken with a Vibracore device as shown in Figure 10. A sufficient quantity of material was gathered at each sampling point to perform necessary laboratory tests. Individual samples were used to run characterization tests on the sediment. Composite samples were used to perform required sedimentation tests.

Sediment Characterization

37. Characterization tests were performed on samples from each sampling location by the Norfolk District. Composite samples were tested and characterized by the Geotechnical Laboratory at WES. In general, the results were similar. The results from the composite tests were used in the designs because these are considered more representative than a numerical mean of the three individual samples. Tests performed included USCS classification, water content, Atterberg limits, specific gravity, and gradation. Test results comparing the new work and maintenance sediment are summarized in Table 1.

Classification.

38. Values of liquid limit and plasticity index for the new work material are plotted in Figure 11 along with the values of the maintenance material as determined in the CIMP. All new work samples were classified as highly plastic clay according to the Unified Soil Classification System (USCS).

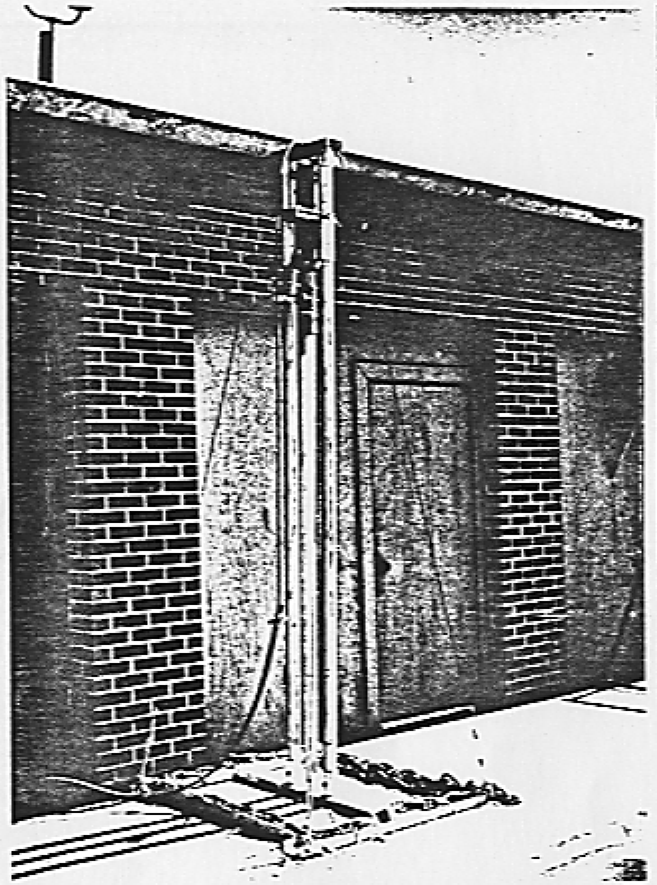

Figure 10. Vibracore sampler.

Table 1

Comparison of Soil Characteristics of

Maintenance and Deepening Sediment

Characteristic	Maintenance Sediment	Deepening Sediment
Specific gravity	2.75	2.70
Sand content	15%	12%
Liquid limit	128	83
Plasticity index	88	58
In-situ water content	205%	108%

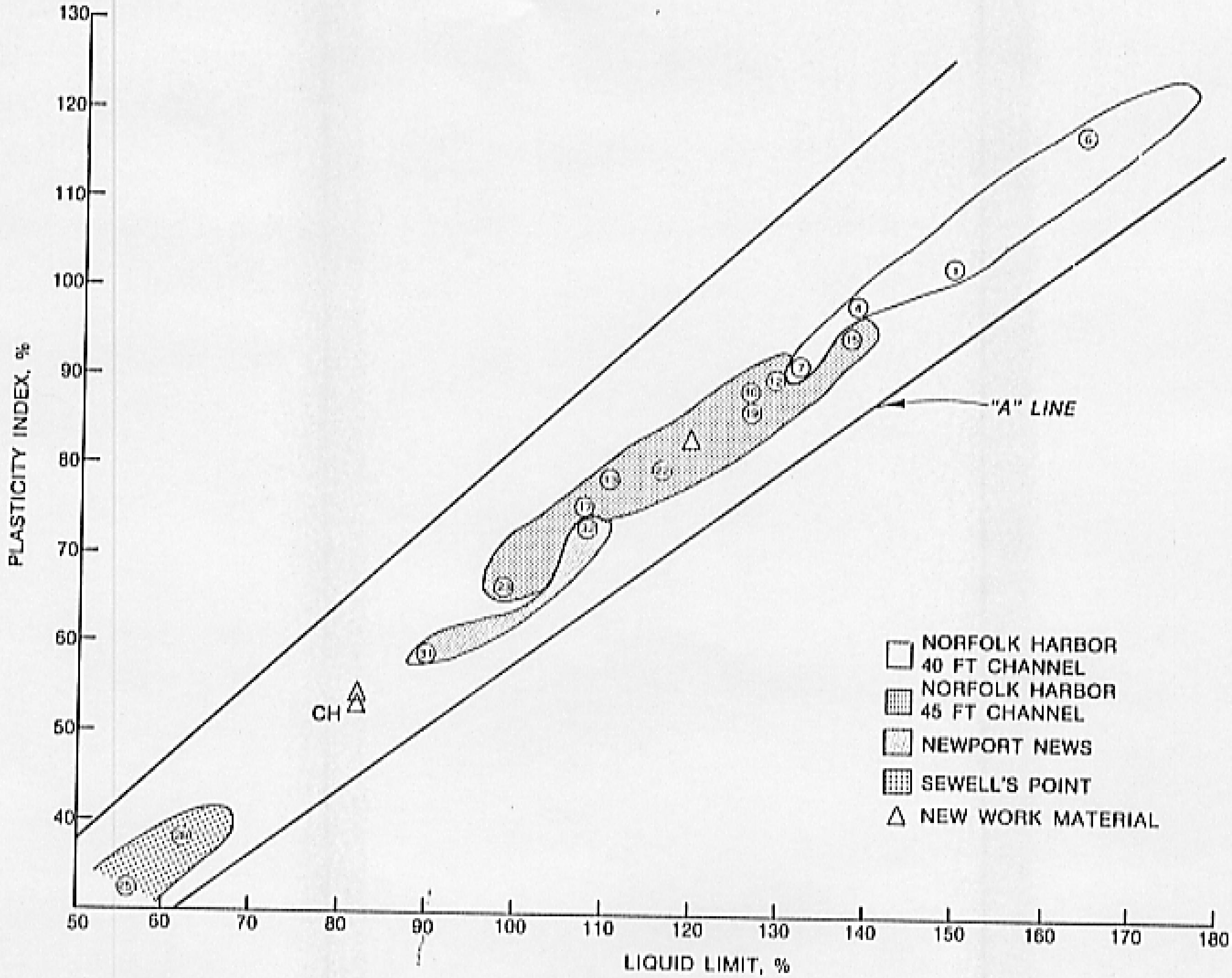

Figure 11: Comparison of new work sediment classification and plasticity to maintenance sediment (Modified from CIMP).

Water content.

39. The in situ water content of the sediment samples ranges from 98 percent to 125 percent with a mean of 108 percent. This is considerably less in situ moisture than the maintenance sediment.

Specific gravity.

40. The specific gravity tests performed on the individual samples had values ranging from 2.66 to 2.75. The specific gravity of the composite sample was 2.70.

Sedimentation Tests

41. All sedimentation tests were performed using an 8-in. diameter plexiglass settling column with a slurry depth of 6 ft in accordance with procedures described in Palermo, et al. (1978). The test results were used to evaluate the settling rate of the fluidized sediment. The sediment samples taken at the three locations were combined and the tests performed on the composite material.

42. A series of zone settling tests was performed on concentrations ranging between 51 g/ℓ and 168 g/ℓ. The zone settling velocity for each test was determined by monitoring the interface height during the test duration. A 15-day settling test was run to determine the thickening properties of the sediment. The mean solids concentration was determined using mass balance relationships as the test progressed. A plot of this mean concentration versus time is shown in Figure 12. Detailed test results are presented in Appendix A.

Consolidation Tests

43. The WES Geotechnical Laboratory performed a fixed-ring consolidation test on a composite sediment sample. The data from this test were used in the storage capacity evaluations described in Part IV. The test consisted of incremental loadings of 0.009, 0.010, 0.025, 0.050, 0.100, 0.250, and 1.00 tsf on the remolded sample. The void ratio versus log pressure relationship is shown in Figure 13. Detailed test results including time-consolidation curves are presented in Appendix B.

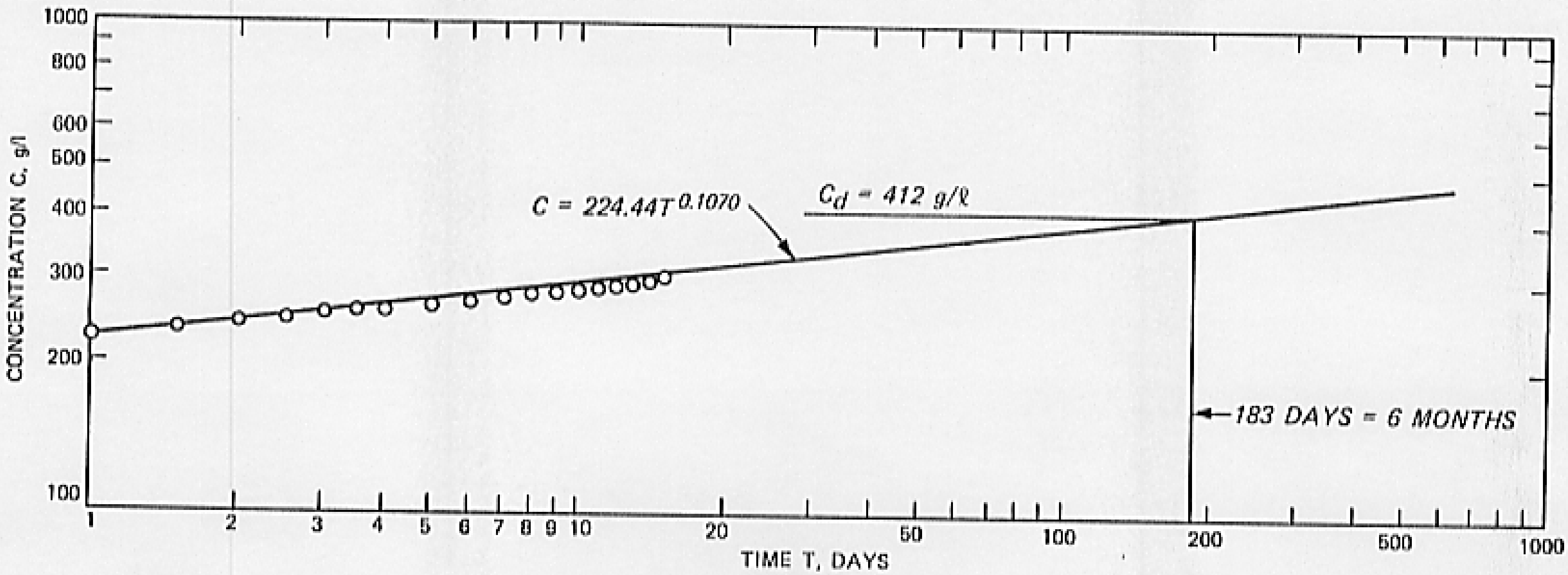

Figure 12: Results from 15-day settling test.

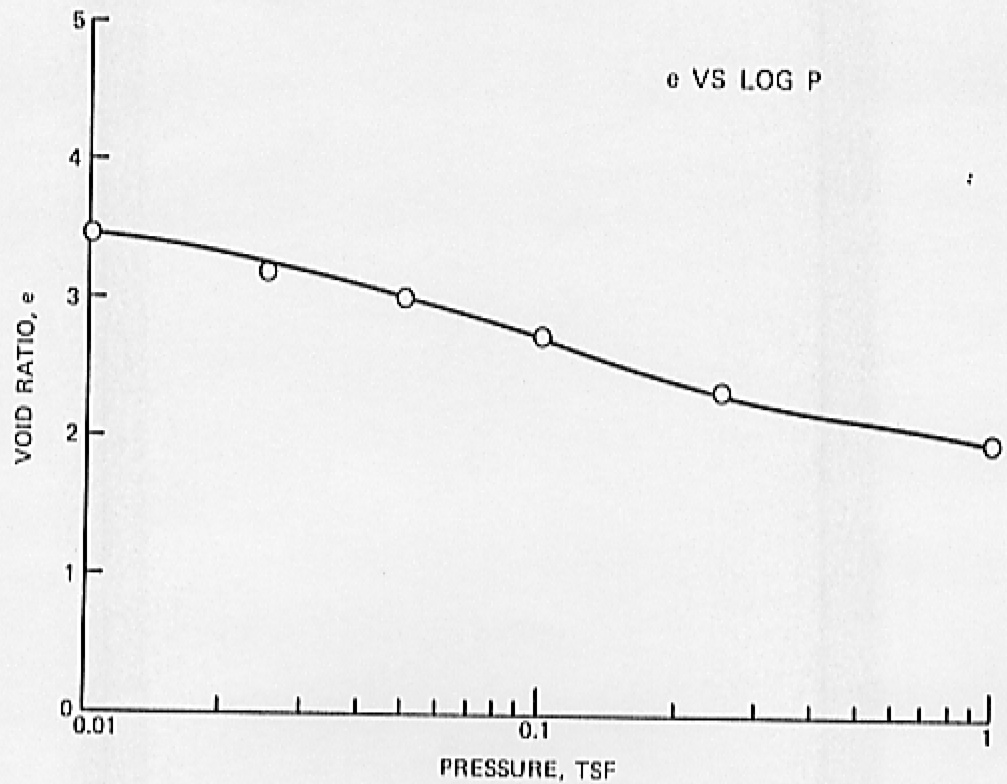

Figure 13: Void ratio versus log pressure for new work sediment.

PART III: WATER QUALITY EVALUATION

Analysis of Data

44. The allowable inflow rate to insure adequate sedimentation in a given disposal area is directly dependent upon the inflow concentration, disposal area characteristics, and sedimentation properties of the dredged material. These relationships and potential interactions are discussed in detail in this section.

45. The results from the zone settling tests as described in Part II are shown in Figure 14. At initial concentrations greater than 150 g/ℓ (9.4 lb/ft^3), the diameter of the settling column was the controlling factor rather than zone settling. Therefore data points at initial concentrations greater than 150 g/ℓ are not valid for evaluation of zone settling and were not used in developing the zone settling velocity versus concentration curve.

46. The relationship between initial solids concentration and zone settling velocity was used to develop the design curve of solids loading versus initial concentration (Figure 15). Solids loading can be defined as the flux of solids passing through an imaginary layer which exists slightly above the solids-liquid interface. It is calculated by the following equation:

$$S = V_s C$$

where

S = solids loading, $lb/hr\text{-}ft^2$

V_s = zone settling velocity, ft/hr

C = initial concentration, lb/ft^3

Evaluation of Sedimentation

47. Rather than presenting a specific basin design, this section contains curves relating parameters for a range of designs. This is required since a maximum allowable inflow rate is desired. The curves presented also allow for rapid determination of any parameter if the

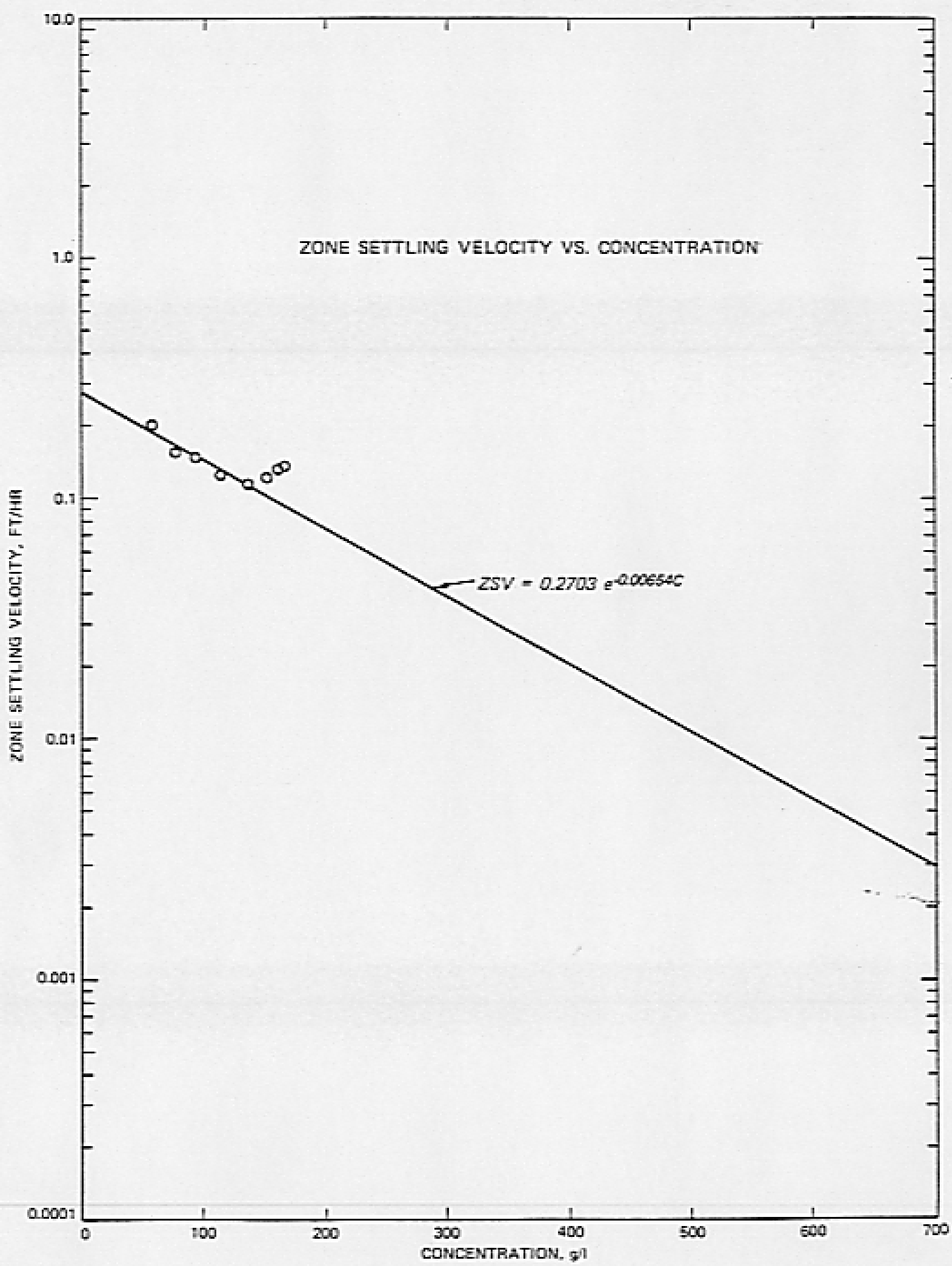

Figure 14: Zone settling velocity versus concentration for new work sediment.

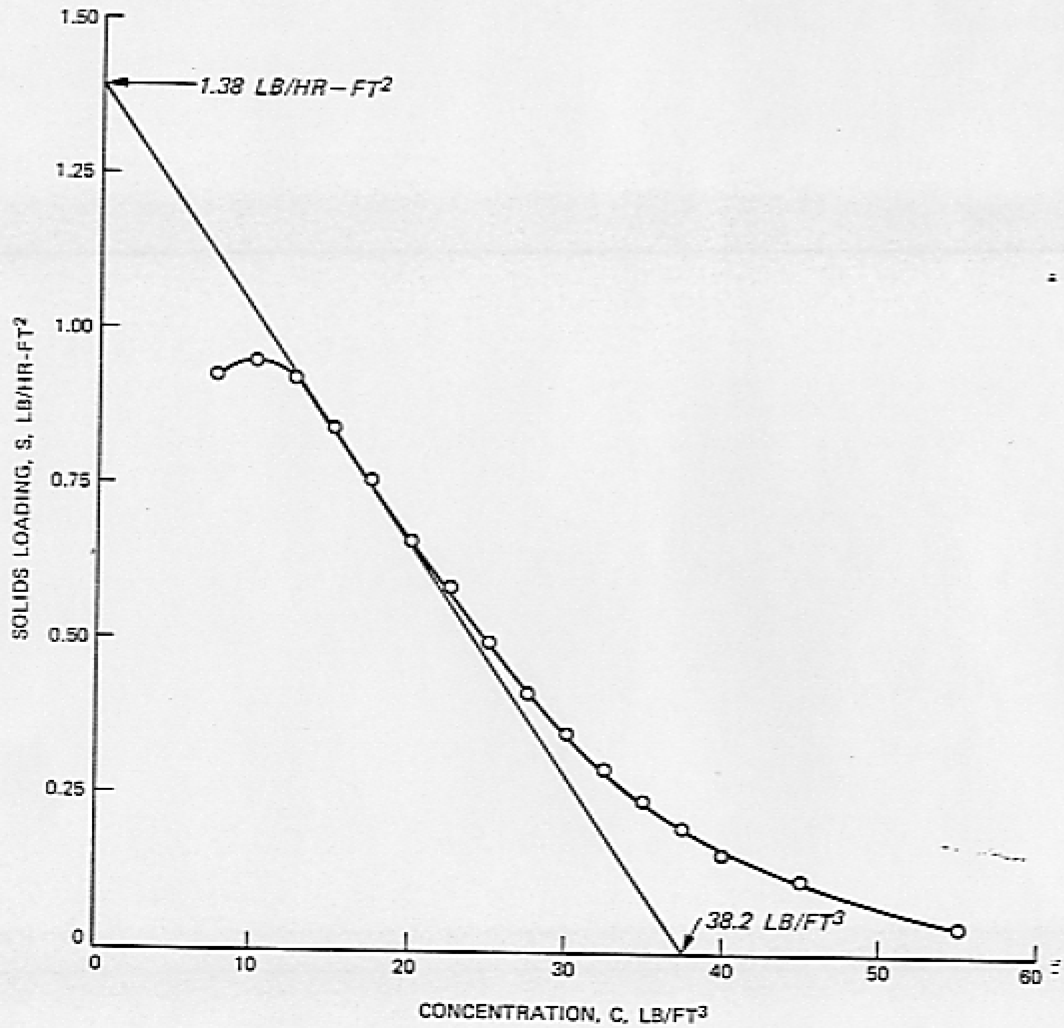

Figure 15: Solids loading curve for the new work sediment.

others are known. It should be noted, however, that these design curves are valid only for the new work sediment.

48. The solids loading curve presented earlier is valid for designing basins in which compression settling (Type IV) controls the design (i.e. requires the larger surface area). The minimum concentration at which this occurs can be determined by extending a tangent, drawn along the largest negative slope of the solids loading curve, to the horizontal axis. This concentration for the new work sediment is shown in Figure 15 as 38.2 lb/ft^3 (611 g/ℓ). Since the average concentration in the basin at the end of the one year dredging cycle should be only 25.7 lb/ft^3 (412 g/ℓ as shown in Figure 12), effluent clarification requires the larger surface area.

49. To provide a sufficient surface area for clarification, the solids must have sufficient time to settle below the withdrawal zone before they reach the weir. The following equation defines this relationship:

$$A = \frac{Q}{ZSV}$$

where

A = ponded surface area, ft^2

Q = overflow rate, ft^3/sec

ZSV = settling velocity of the solids, ft/hr

Because the surface area is known and defining the maximum allowable inflow is the major concern, this equation can be rearranged and the equation for zone settling velocity from Figure 14 inserted to obtain the following relationship between influent solids concentration, ponded surface area, and inflow rate:

$$Q = 3.271\ Ae^{-0.00654C}$$

where

A = ponded surface area, acres

C = influent solids concentration, g/ℓ

Q = inflow rate, ft^3/sec (assuming inflow rate = overflow rate)

Figure 16 illustrates this relationship.

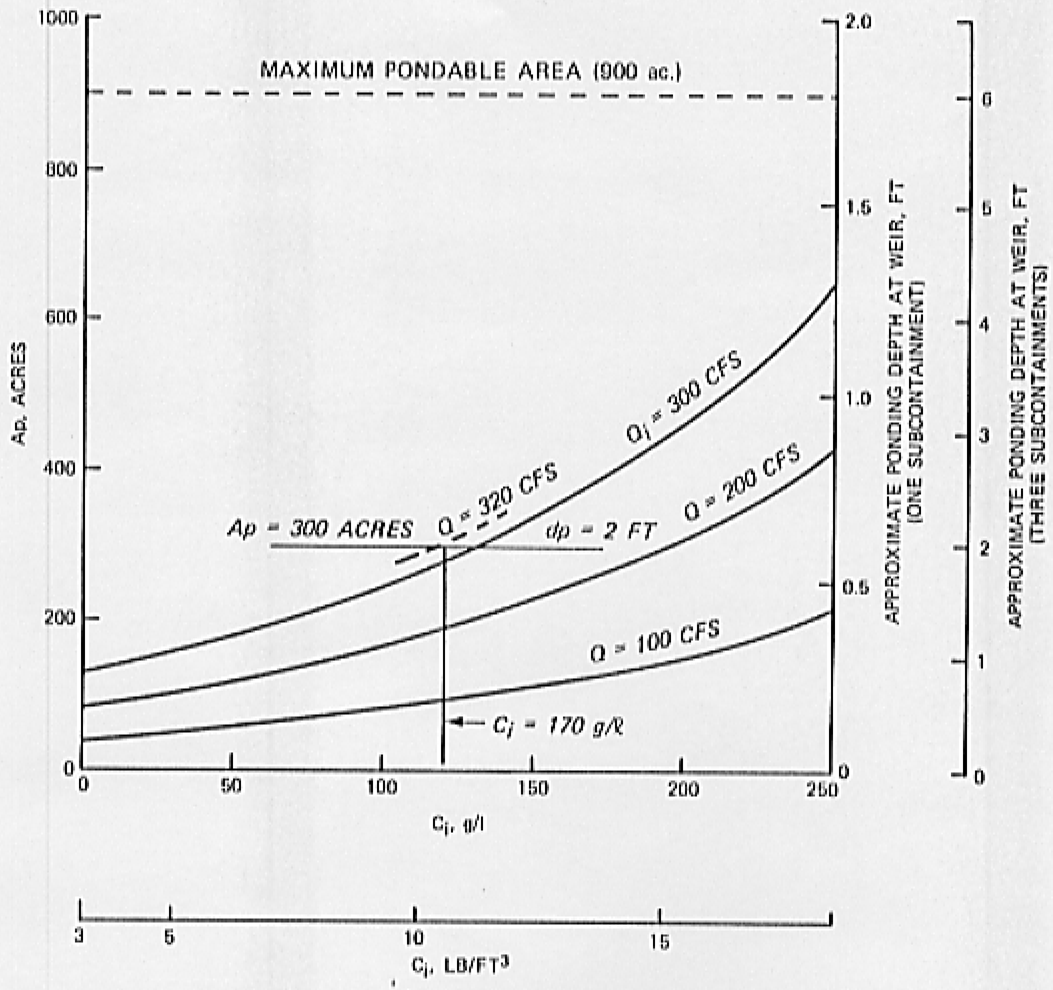

Figure 16: Relationship of inflow concentration versus ponded area and ponded depth for various inflow rates.

50. Samples of discharge into Craney Island recorded in the CIMP had a mean solids concentration of 168 g/ℓ. Assuming the discharge concentration is 170 g/ℓ and the ponded surface area is 300 acres, which is equivalent to the minimum ponding depth of 2 feet at the weir for the 3 subcontainment configuration, Figure 16 shows an allowable inflow of 320 cfs. This restricting condition is the equivalent of five 30-inch dredges discharging at a velocity of 12 ft/sec (Table 2). Since such a situation is very unlikely, it can be concluded that sedimentation should not limit inflow rate.

Weir Evaluation

51. The nomogram for evaluation of weir designs for a saltwater clay dredged material is shown in Figure 17. From the lower half of the nomogram, the effluent suspended solids concentration should not exceed 1 g/ℓ for a weir loading of 1.63 cfs/ft and the minimum ponded depth of 2.0 ft. This corresponds to an inflow rate of 245 cfs for the 150 ft weir lengths recommended in the CIMP.

52. The depth of flow over the weir is defined by

$$H = 0.85 \left(0.3 \ \frac{Q}{B}\right)^{2/3}$$

where

H = depth of flow over weir, ft

$\frac{Q}{B}$ = weir loading, cfs/ft

For a weir loading of 1.63 cfs/ft this depth equals 6.3 in. This value should not cause excessive scour of settled material or degradation of water quality.

Table 2

Discharge as a Function of Velocity for

Various Sizes of Dredge Pipe

Discharge Velocity ft/sec	Discharge Output ft^3/sec											
	6	8	10	12	14	16	18	20	24	27	30	36
10	2.0	3.5	5.5	7.9	11	14	18	22	31	40	49	71
11	2.2	3.8	6.0	8.6	12	15	19	24	35	44	54	78
12	2.4	4.2	6.5	9.4	13	17	21	26	38	48	59	85
13	2.6	4.5	7.1	10.0	14	18	23	28	41	52	64	92
14	2.7	4.9	7.6	11.0	15	20	25	31	44	56	69	99
15	2.9	5.2	8.2	12.0	16	21	27	33	47	60	74	106
16	3.1	5.6	8.7	13.0	17	22	28	35	50	64	79	113
17	3.3	5.9	9.3	13.0	18	24	30	37	53	68	83	120
18	3.5	6.3	9.8	14.0	19	25	32	39	57	72	88	127
19	3.7	6.6	10.0	15.0	20	27	34	41	60	76	93	134
20	3.9	7.0	11.0	16.0	21	28	35	44	63	80	98	141
21	4.1	7.3	11.0	16.0	22	29	37	46	66	83	103	148
22	4.3	7.7	12.0	17.0	24	31	39	48	69	87	108	156
23	4.5	8.0	13.0	18.0	25	32	41	50	72	91	113	163
24	4.7	8.4	13.0	19.0	26	34	42	52	75	95	118	170
25	4.9	8.7	14.0	20.0	27	35	44	55	79	99	123	177

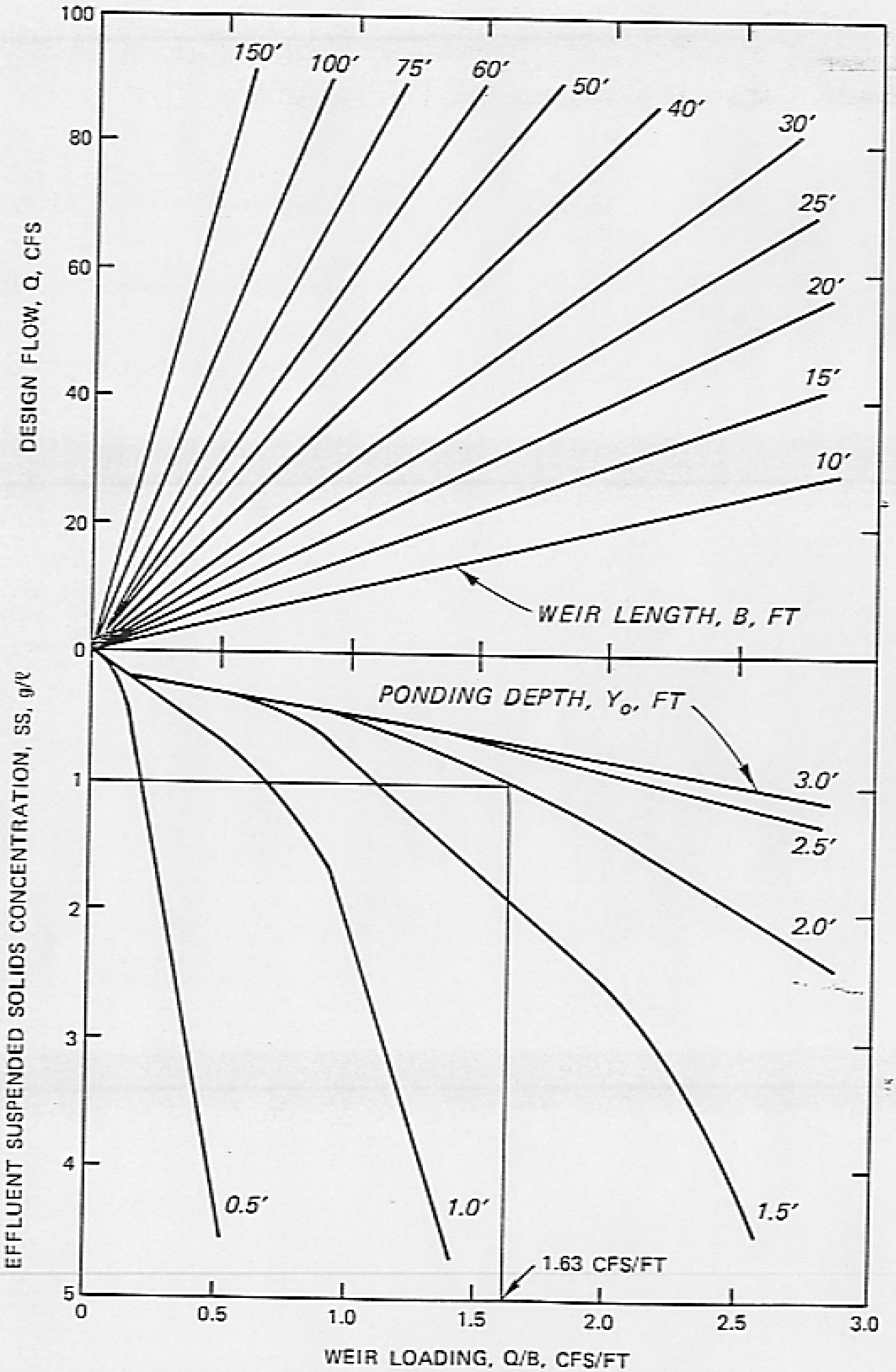

Figure 17: Nomogram relating weir design parameters (after Walski and Schroeder 1978).

PART IV: STORAGE CAPACITY EVALUATION

Consideration of Subcontainments

53. There are several subcontainment configurations that are possible for the Craney Island Disposal Area while the harbor deepening is being completed. These include the disposal area as one large 2250-acre containment area, three equal sized subcontainments of 750 acres each, as proposed in the CIMP or four equally sized subcontainments of 750 acres each, with the expansion area designated for initial placement of part or all of the new work material. Each of these alternatives was evaluated using loading simulations similar to those in the CIMP. The storage capacity for each configuration was estimated and the alternatives compared. Factors such as constructability, ease of maintenance, and practicability were considered along with the economic advantages.

Constructability

54. Considerable attention must be directed toward coordinating construction progress and the deepening effort. The CIMP presented a staged construction sequence which included extending the existing spur dikes across the containment area. As construction advances westward, foundation conditions progressively worsen. If these dikes cannot be completed before the deepening work begins, problems encountered in their completion could compound. Also, as the interior dike construction progresses, an increase in flow during the deepening work could make their completion more difficult due to potential scour. Proper management of the locations of inflow pipes should help deter this scour problem. Figure 18 illustrates the potential scour area resulting from inflow location 1 and the effect of moving the inflow to location 2 for a given set of weirs in operation. The increase in flow should not increase the amount of surface or ponded water significantly. The accelerated completion of one of the interior dikes would alleviate this problem by eliminating the flow from two-thirds of the basin and, as the drying progressed, completion of the other interior dike would become

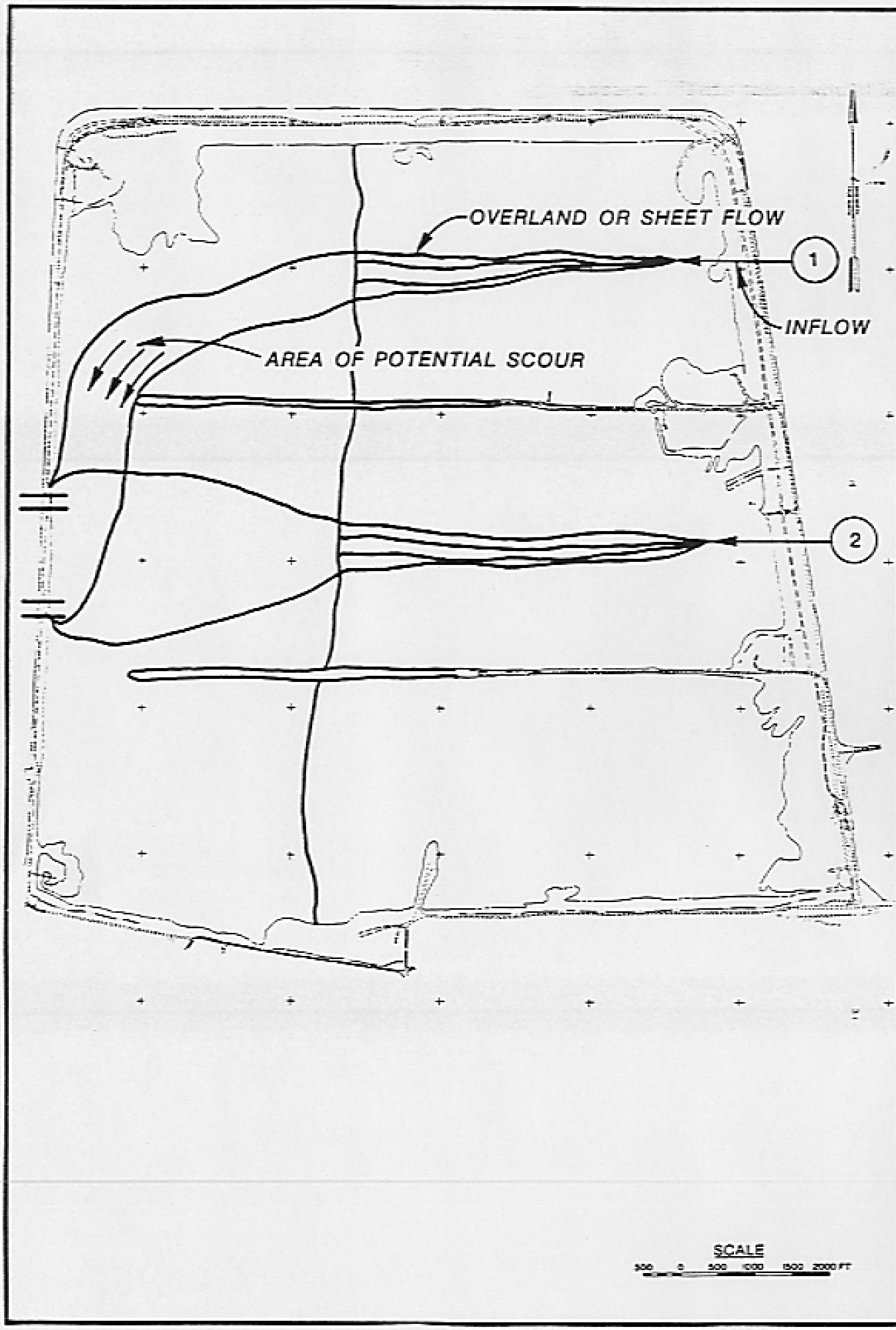

Figure 18: Points of inflow and weirs for interim operation (from CIMP).

easier. This also would allow for easier weir construction and the dike raising could be accelerated.

55. The surface projections as presented later in this section should be used to evaluate the required dike construction rate during deepening. It should be noted that the projections presented are for the first of the three subcontainments used in the annual rotation scheme. This coordination is probably the most important factor to be considered in implementing this type of construction sequence.

56. A westward expansion could be constructed to store the new work material and the maintenance material dredged during part or all of the deepening period. This would allow several years for the material in Craney Island to desiccate, dewater, and consolidate. The conversion of Craney Island to the three subcontainment configuration could also take place during this time and could be accomplished under easier working conditions. Appendix B presents construction suggestions for a westward expansion.

Factors Affecting Storage Capacity

57. Once the sedimentation process is complete, additional densification of the dredged material results from consolidation, dewatering, and desiccation. The increase in storage volume obtained from densification is a very important consideration in evaluating the long-term storage capacity of the containment area.

58. Consolidation is a slow, almost continuous process. Not only will the dredged material undergo self-weight consolidation, but the load applied by the dredged material layer also results in consolidation of the foundation material. Evaluation of dredged material and foundation consolidation was accomplished as part of the overall storage capacity evaluation using similar procedures as outlined in the CIMP.

Desiccation

59. Additional surface subsidence will occur through evaporative desiccation. Depending upon the surface area of material exposed for

evaporation, the time of exposure, and the evaporation rate, this desiccation can yield a substantial storage volume gain. Desiccation was found to be the overriding factor in the comparison of management alternatives found in the CIMP. The procedures used to evaluate this desiccation are outlined by Haliburton (1978).

Dewatering Operations

60. Desiccation can be improved by increasing efficiency of surface water drainage. An active dewatering program consisting of progressive surface trenching should accomplish these goals. A detailed discussion of desiccation and dewatering along with reclamation and use is presented in Part VI and Part VII of the CIMP. The same analysis and implications apply directly to the deepening case.

Mathematical Model

61. The mathematical model used to predict the surface subsidence due to consolidation and desiccation is a modified version of the PROCON model (Johnson 1976). Minor changes have been made from the version used in the CIMP to limit the depth effected by dewatering to the depth of the last lift applied and to limit the minimum water content to 1.4 times the plastic limit of the sediment.

62. The model for simulating the filling process utilizes the theory of consolidation developed by Terzaghi (1948). This theory assumes that hydraulic limitations determine the amount of volume change. The volume change is equal to the volume of water squeezed out of the soil and the degree of consolidation can be computed at any depth and time.

63. Three coefficients must be determined for use in the model; the coefficient of volume compressibility, coefficient of consolidation, and coefficient of permeability; each is a function of log pressure.

64. The coefficient of volume compressibility is the change in porosity per unit change in pressure. It can be calculated by the equation

$$m_v = \frac{a_v}{1 + e_o}$$

where

a_v = coefficient of compressibility $- \frac{e_o - e_1}{p_1 - p_o}$

e_o = void ratio before increase in pressure

e_1 = final void ratio for loading

p_1 = pressure of loading

p_o = initial pressure

The coefficient of consolidation is defined as follows:

$$C_v = \frac{T_v}{t} H^2$$

where

T_v = time factor for 50 percent consolidation = 0.197

t = time for sample to reach 50 percent consolidation

H = mean flow path of pore water

The coefficient of permeability of the sample during any given load increment may be computed as follows:

$$K = C_v \, q_w \, M_v$$

where K = coefficient of permeability

C_v = coefficient of consolidation

q_w = density of water = 62.4 lb/ft^3

M_v = coefficient of volume change

The relationship of these coefficients to log pressure are shown in Figures 19, 20, and 21.

Selection of Parameters

65. Data requirements for using the modified PROCON model include:

   a. Dredging schedule.

   b. Lift thickness for disposal operations.

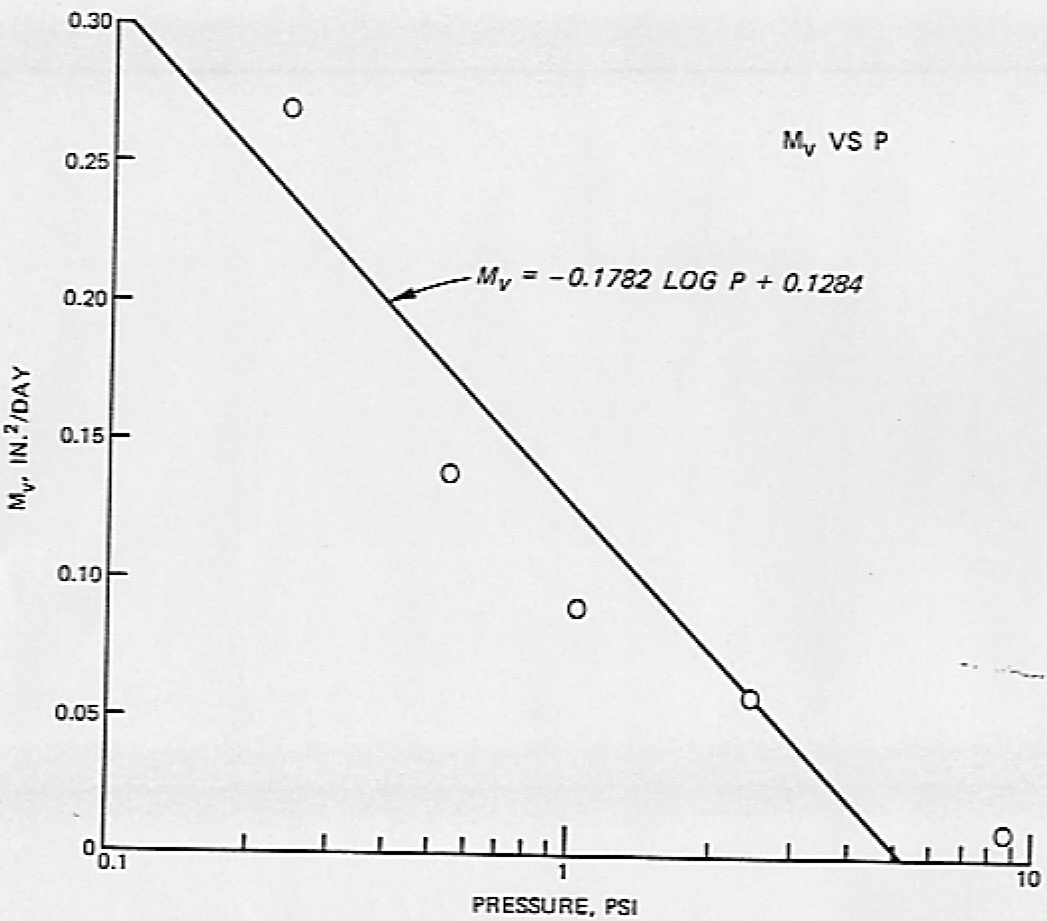

Figure 19: Coefficient of volume compressibility versus log pressure.

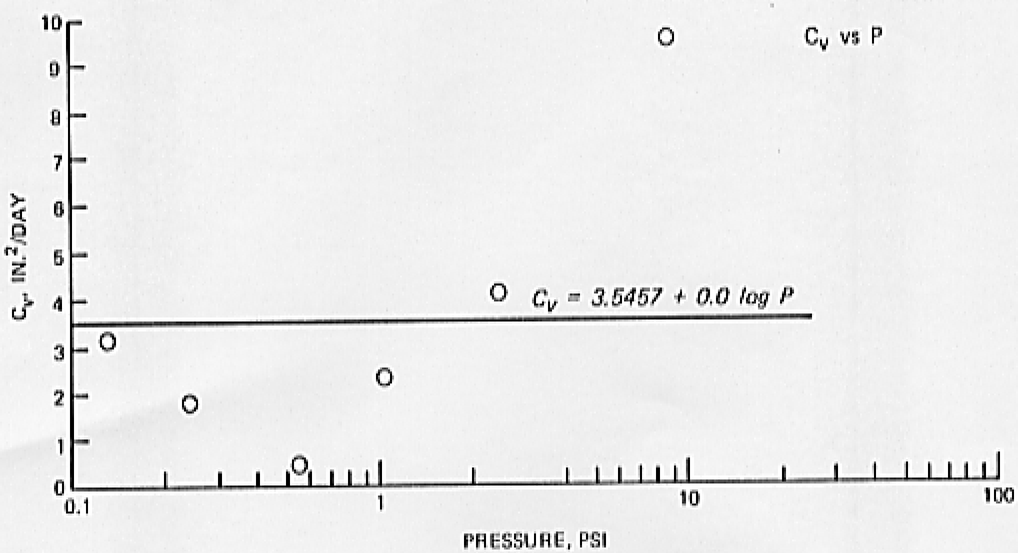

Figure 20: Coefficient of volume change versus log pressure.

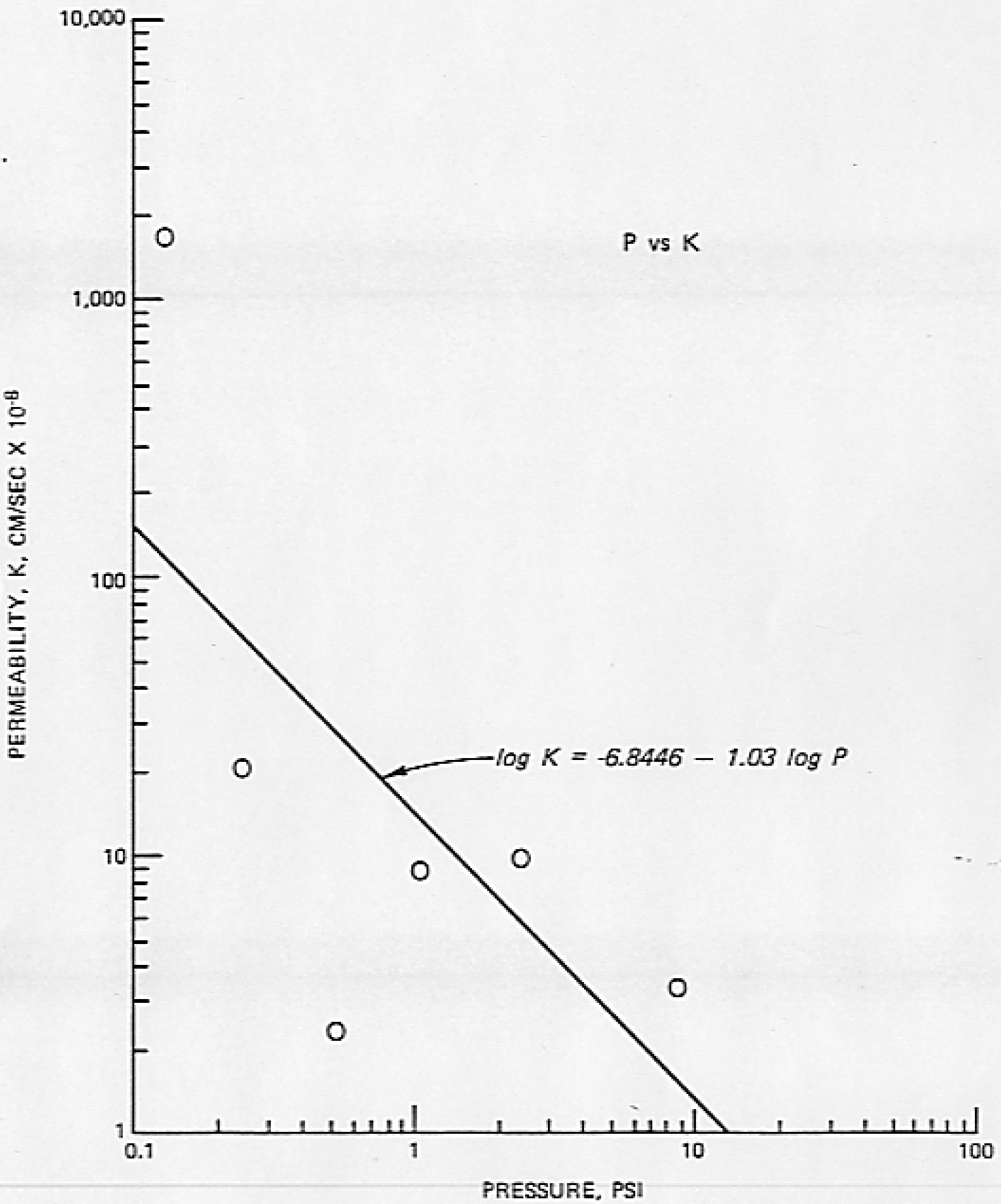

Figure 21: Coefficient of permeability versus log pressure.

c. Consolidation properties of foundation soils and existing dredged material layers.

d. Consolidation properties of sediments to be dredged.

e. Desiccation properties of sediments to be dredged.

Where appropriate these data are presented for each of the construction alternatives.

Dredging Schedule

66. Since an actual dredging schedule was not available, a preliminary construction sequence furnished by the Norfolk District (Norfolk District 1980) was used to establish a reasonable and representative schedule. A constant dredging rate throughout the deepening work is a reasonable approximation of the probable construction sequence. Figure 22 shows the accumulated volume dredged with time assuming a constant dredging rate for a 4 and an 8 year dredging period.

Lift Thickness

67. The thickness of the dredged material layer at the completion of dredging cycles is a function of dredging time, volume and void ratio of the in situ sediment, the volume and void ratio of the dredged material at the completion of dredging, and the surface area available for storage. The volume of material to be dredged during the deepening project includes both maintenance and new work material. A normal yearly maintenance volume, according to the CIMP, is approximately 5 million cubic yards of channel sediment. For the period of the deepening work, an annual maintenance volume of 3 million cubic yards per year is assumed for the storage capacity projections to account for the volume of sediment included in the deepening that would normally be dredged as maintenance material. The volume of new work sediment for each year can be determined from Figure 22.

68. The procedures outlined in Palermo, et al. (1978) were used to determine the relationship between in situ sediment properties in the channel and that for material as placed in the disposal area for a 1 containment and 3 subcontainment configuration respectively. The void

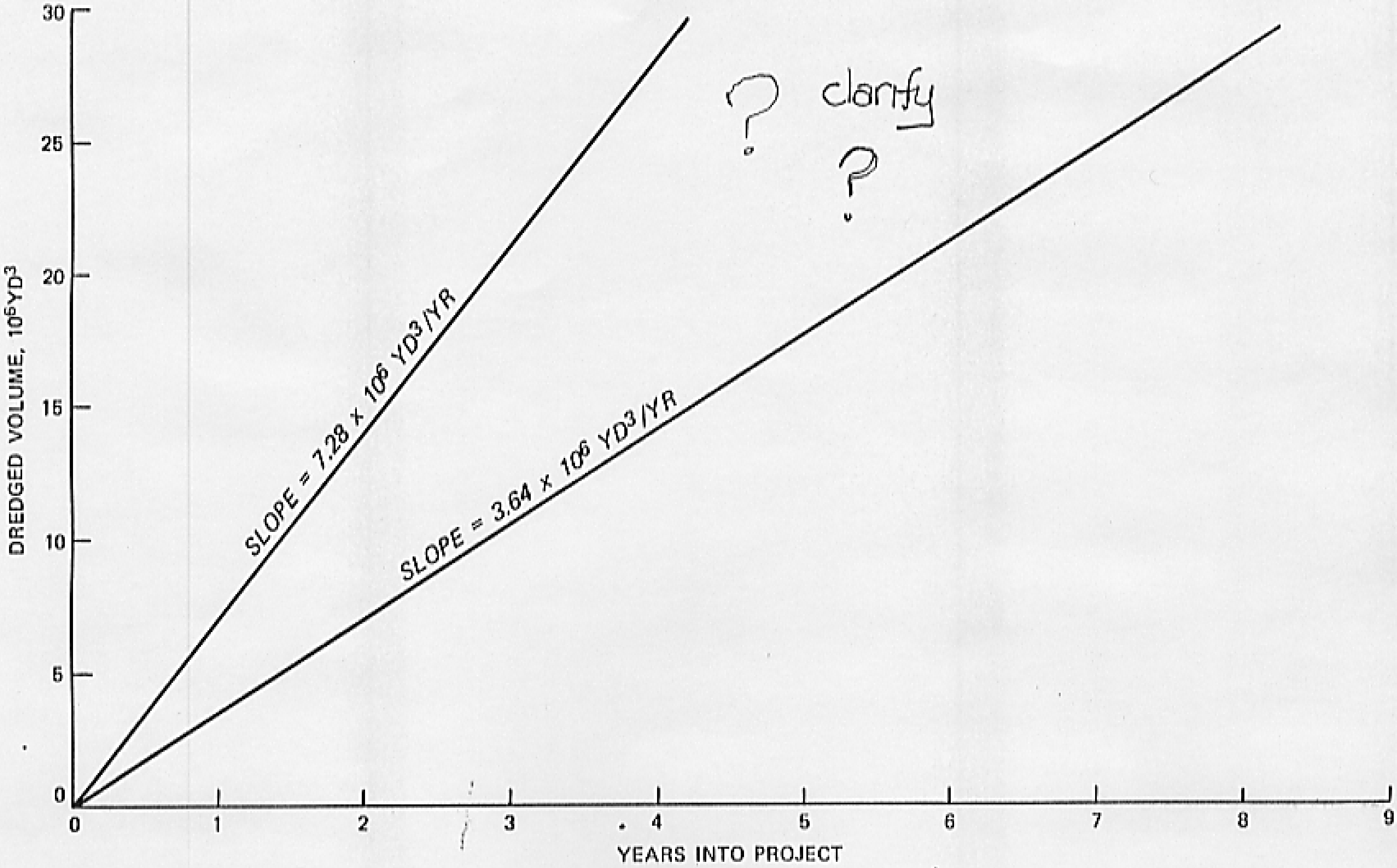

Figure 22: Dredged volume versus time.

ratio of the in situ channel sediment can be computed from the properties listed in Table 1 by the equation

$$e_i = \frac{WG_s}{S_d}$$

where

e_i = void ratio of the in situ channel sediment

W = water content of the in situ channel sediment

S_d = degree of saturation = 100 percent

The void ratio in the containment area at the completion of the dredging cycle is defined by

$$e_o = \frac{G_s \gamma_w}{\gamma_d} - 1$$

where

e_o = void ratio of the sediment in the containment area at the completion of dredging

γ_w = density of water

γ_d = density of sediment in the containment area at the completion of dredging

G_s = specific gravity of sediment

The average void ratio for the sediment at the end of a one-year dredging cycle will be 5.5 (from Figure 12). The volume of material in the containment area is calculated by

$$V_t = V_{sd} + V_f$$

where

V_t = volume of the material in the containment area at the completion of the dredging cycle

V_{sd} = volume of sand

V_i = in situ volume of fine-grained sediment

V_f = volume of fine-grained sediment

The final volume of fine-grained sediment is determined by the equation

$$V_f = V_i \left(1 + \frac{e_o - e_i}{1 + e_i}\right)$$

The anticipated lift thickness can now be calculated by dividing by the surface area. For 1 containment area of 2250 acres, an annual lift thickness of 4.26 feet for deepening and maintenance material is estimated. For 3 subcontainments of 750 acres each, this thickness is 12.79 feet. Note that the projected lift thicknesses will be the same for the westward expansion as for the 3 subcontainment configuration.

DOES THIS HEIGHT INCLUDE 2' TO 3' PONDING DEPTH
IF NOT DOES THIS MEAN THAT DIKES SURROUNDING EACH SUBCONTAINMENT AREA ARE TO BE 12.79' IN HEIGHT PLUS A FREE BOARD ALLOWANCE OF SAY 2.0' OVER THE PONDING DEPTH
H = 12.79+3.0+2.0 = 17.79' ???

Consolidation Parameters

69. Selection of consolidation parameters for the channel sediment and in-place dredged material was based on the consolidation tests described in Part II. Parameters for foundation soils were selected based on the original disposal area design data.

70. The modified PROCON model requires consolidation parameters for sediments to be dredged in the following forms:

$$C_v = A1 + B1 \log_{10} P$$
$$M_v = A2 + B2 \log_{10} P$$
$$\log_{10} K = A3 + B3 \log_{10} P$$

where

C_v = coefficient of consolidation, in.^{2}/day

M_v = coefficient of volume change, in.^{2}/lb

K = coefficient of permeability, cm/sec

P = effective pressure, lb/in.^{2}

A and B = model input parameters for which the appropriate coefficients may be computed for the effective pressure existing at a given point

71. The input parameters used for the sediment were a weighted average of those determined by least squares fits for the new work and maintenance sediment. The values for the maintenance sediment are those used in the CIMP. A summary of these constants is tabulated below.

Constant	New Work	Maintenance	Weighted Average*
A1	3.5457	6.8517	4.7946
B1	0.0	0.0	0.0
A2	0.1284	0.2350	0.1687
B2	-0.1782	-0.2950	-0.2223
A3	-6.5370	-6.8446	-6.7284
B3	-0.5506	-1.0300	-0.8489
—	—	—	—

* Weighted average based on the average volume of new work and maintenance sediment dredged each year.

72. Consolidation parameters used for the foundation soils are those used in the CIMP. It was assumed that no consolidation occurred below el -60.0. The in-place dredged material was considered to be a foundation soil and the consolidation parameters were considered not to be a function of effective pressure. The values are tabulated as follows:

Foundation Soil	Elevation ft From	To	C_v in.^{2}/day	K cm/sec	M_v in.^{2}/lb
Dredged material	+15.0	-10.0	5.47	2.34×10^{-7}	0.071
Foundation Zone A	-10.0	-30.0	0.47	5.40×10^{-7}	0.017
Foundation Zone B	-30.0	-60.0	0.67	2.4×10^{-7}	0.015

Dessication Parameters

73. The surface subsidence of the dredged material is enhanced by evaporation of excess water through desiccation. The effective rate of evaporation is directly related to the degree of infiltration of precipitation occurring during the period of drying and the area exposed to drying.

74. Table 3 summarizes the annual precipitation and evaporation data for the Norfolk area. A seven-month period in which precipitation is less than evaporation occurs from April to October. It is during this period that desiccation will occur over the exposed surface of the disposal area.

Table 3

Average Monthly Precipitation and Pan Evaporation Rates for the Norfolk, Virginia, Area (from CIMP)

Month	Precipitation* in.	Pan Evaporation** in.	Excess Evaporation, in. 100 Percent Infiltration	75 Percent Infiltration
January	3.4	0.0	--	--
February	3.3	0.6	--	--
March	3.4	1.0	--	--
April	2.7	4.5	1.8	2.4
May	3.3	7.0	3.7	4.5
June	3.6	7.7	4.1	5.0
July	5.7	7.7	2.0	3.4
August	5.9	6.6	0.7	2.2
September	4.2	4.9	0.7	2.2
October	3.1	3.6	0.5	1.3
November	2.9	1.2	--	--
December	3.1	0.0	--	--
Total	44.6	44.8	13.5	20.5

* From records of climatological data, Norfolk, Virginia.

** From combined records at Norfolk and Holland, Virginia.

75. The ponding conditions used for computing the desiccation after the deepening work is completed are those used in the CIMP. During this deepening project, however, 40 percent of the surface area was assumed to be ponded for the entire year. No desiccation can occur and, hence, was not considered for this inundated portion or for the surface of the proposed westward expansion while it remains below mean low water. Table 4 shows the desiccation properties of the material during both the deepening phase and maintenance phase. These values were computed using the procedures outlined in Haliburton (1978).

Storage Capacity Projections

76. The modified PROCON model was used to make projections of surface elevation versus time. The parameters used in the model were those used in the CIMP where appropriate. The elevations refer to average surface elevation for the entire subcontainment.

77. The projections begin at an initial surface elevation of +18.0 ft MLW as projected in the CIMP for January 1984 and +19.5 ft MLW as projected for January 1986. This initial surface elevation should be adjusted once an initial start date for deepening is set. Foundation analyses (Norfolk District 1971) have indicated that construction of the main retaining dikes to +30 ft is possible. This elevation also was recommended in the CIMP as the maximum surface elevation allowed without additional foundation analysis. Hence, this maximum surface elevation of +30 ft MLW was chosen for comparison of the alternatives.

78. The projections are consistent with alternative 3 in the CIMP where an active surface water management and dewatering program is assured. The shrinkage due to desiccation, however, was limited to 1.4 times the plastic limit or to an effective dewatering depth equal to the lift thickness, whichever results in the least shrinkage. The equations used for desiccation can be found in Haliburton (1978).

79. The surface elevation projections for the three construction alternatives are shown in Figures 23-28. These projections show that using either alternative 1 or 2, the remaining storage volume in Craney Island will be exhausted prior to or by the end of the deepening project. Figures 27 and 28 show that the storage volume of a 750 acre

Table 4

Water Loss and Surface Subsidence Rates

Due to Desiccation

Material	Number of Subcontainments	Dredging Cycle	Effected Depth in.	Surface Subsidence in./year
Maintenance	1	—	6.4	4.0
	3,4	Active	6.0	3.6
		Inactive	19.4	12.2
Deepening	1	—	5.7	3.6
	3,4	Active	5.7	3.6
		Inactive	20.7	13.1
Combination	1	—	5.9	3.8
	3,4	Active	5.8	3.6
		Inactive	20.2	12.8

Note: Desiccation does not occur when the surface is inundated.

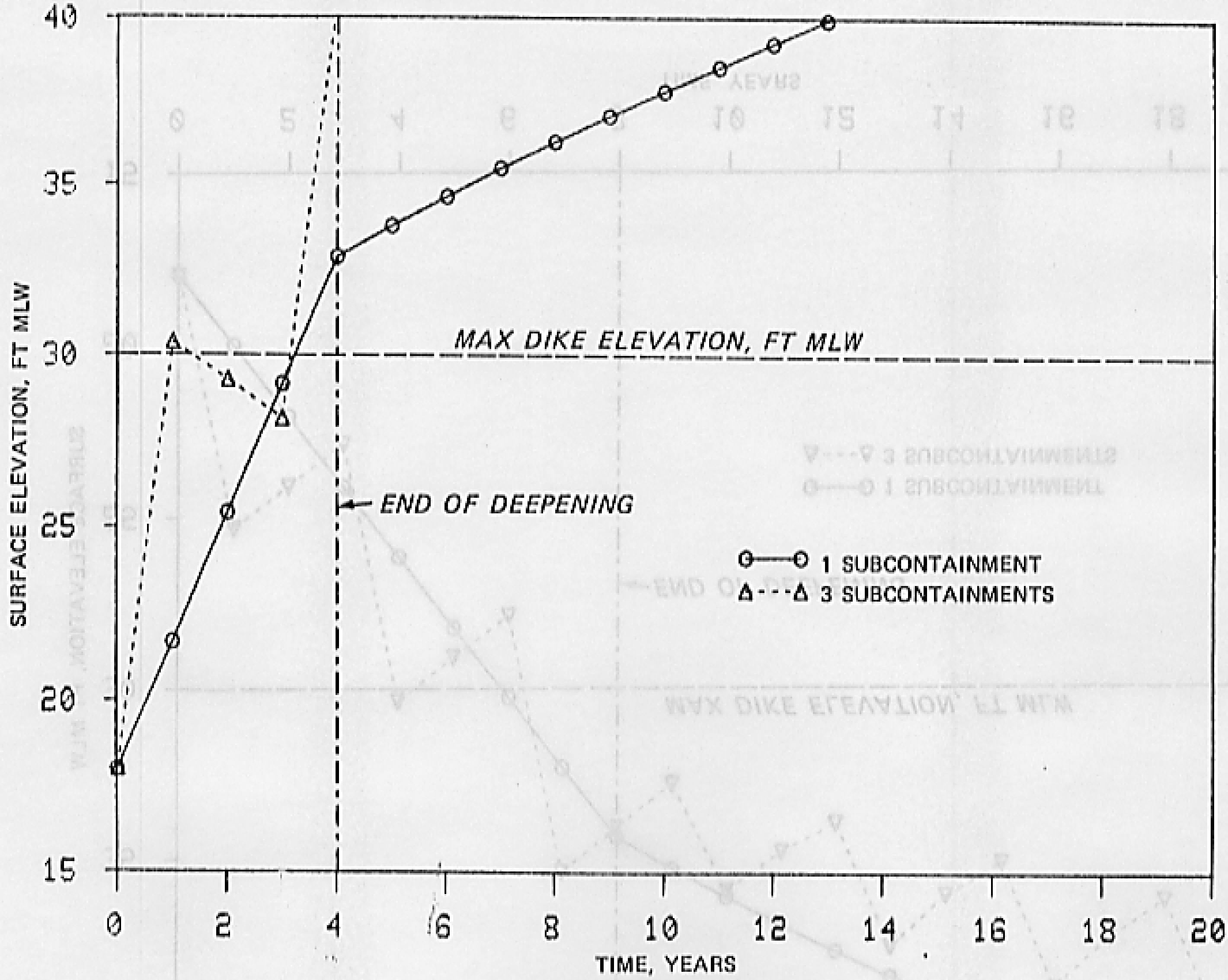

Figure 23: Alternatives 1 and 2 with deepening beginning in January 1984 for 4 years.

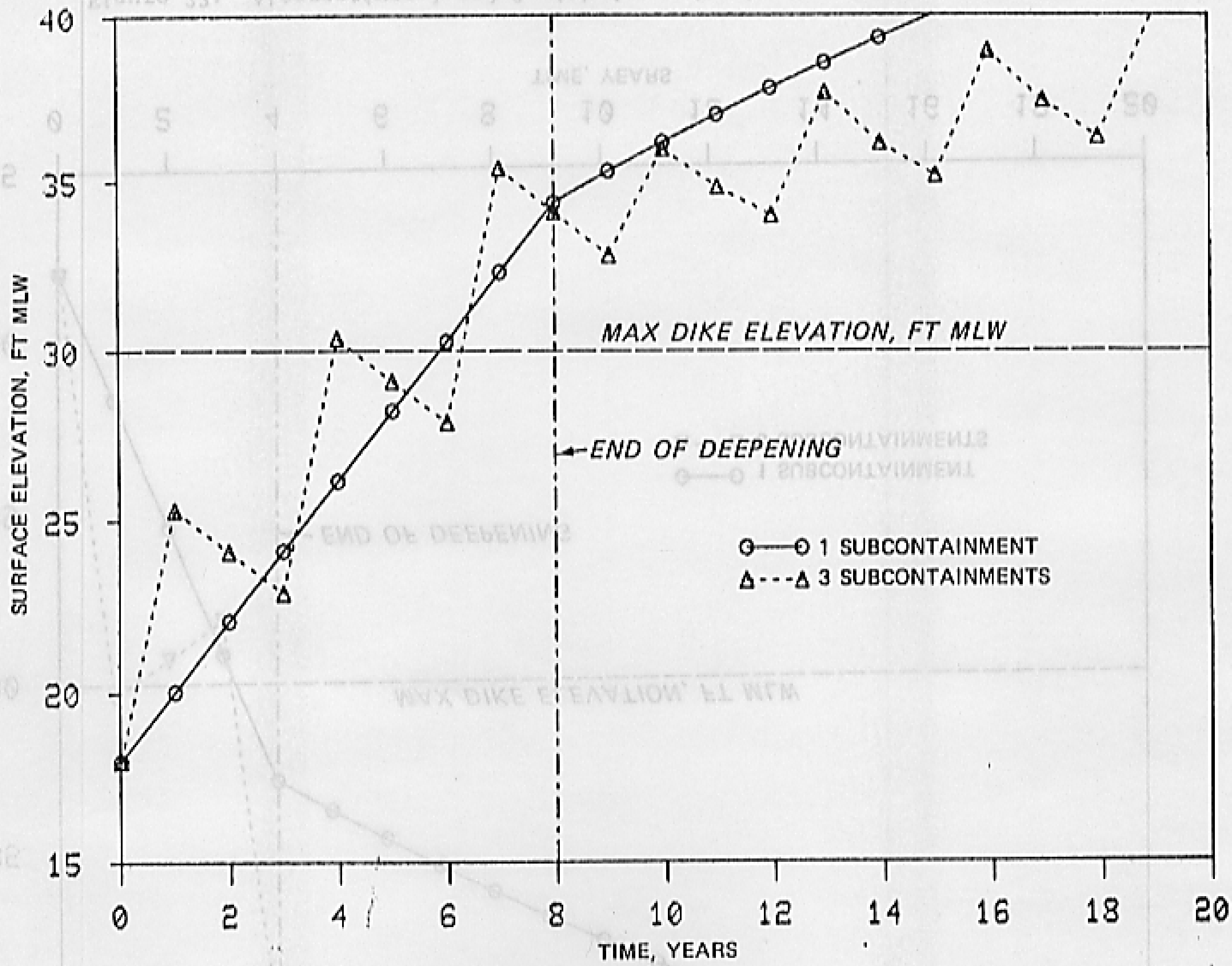

Figure 24: Alternatives 1 and 2 with deepening beginning in January 1984 for 8 years.

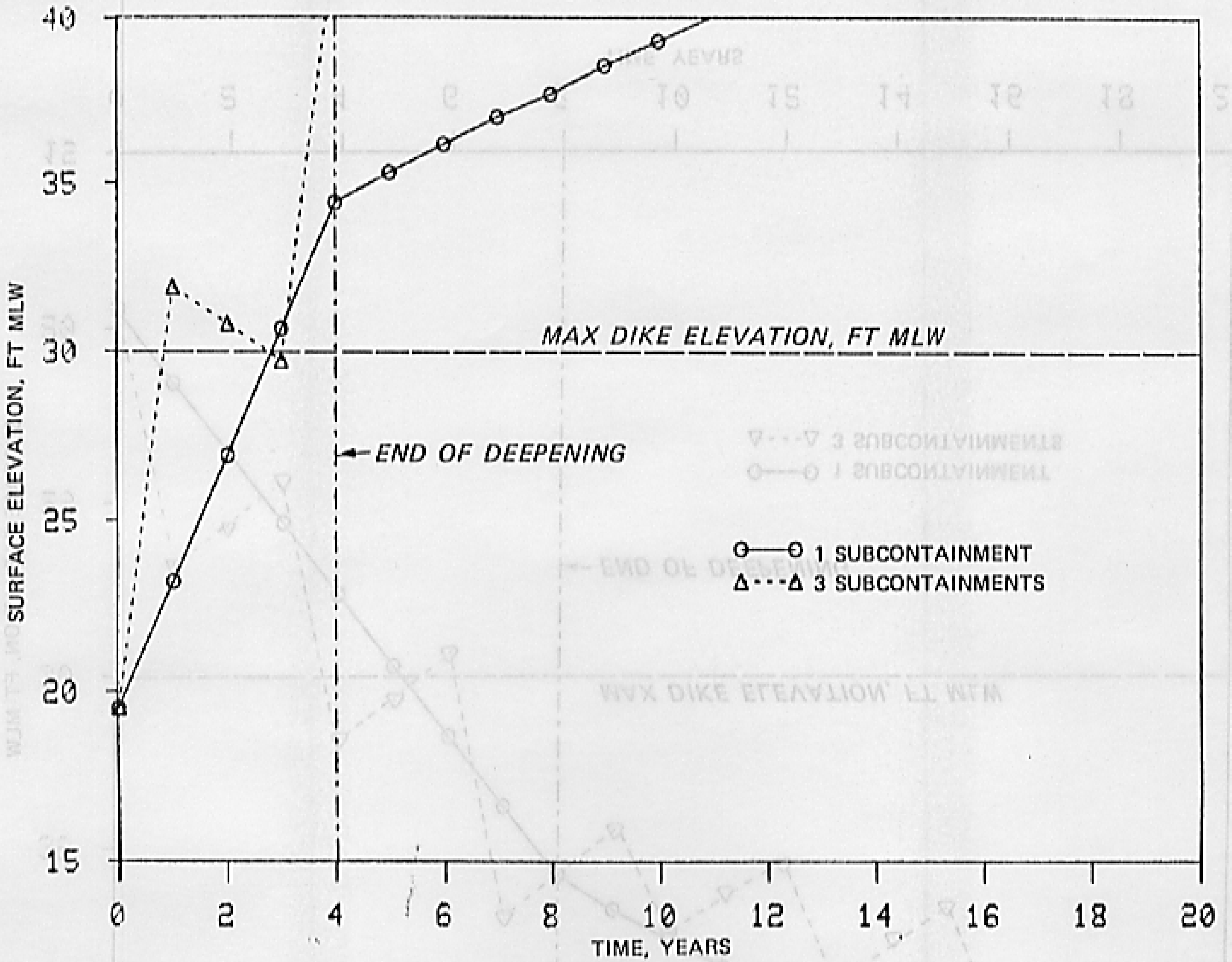

Figure 25: Alternatives 1 and 2 with deepening beginning in January 1986 for 4 years.

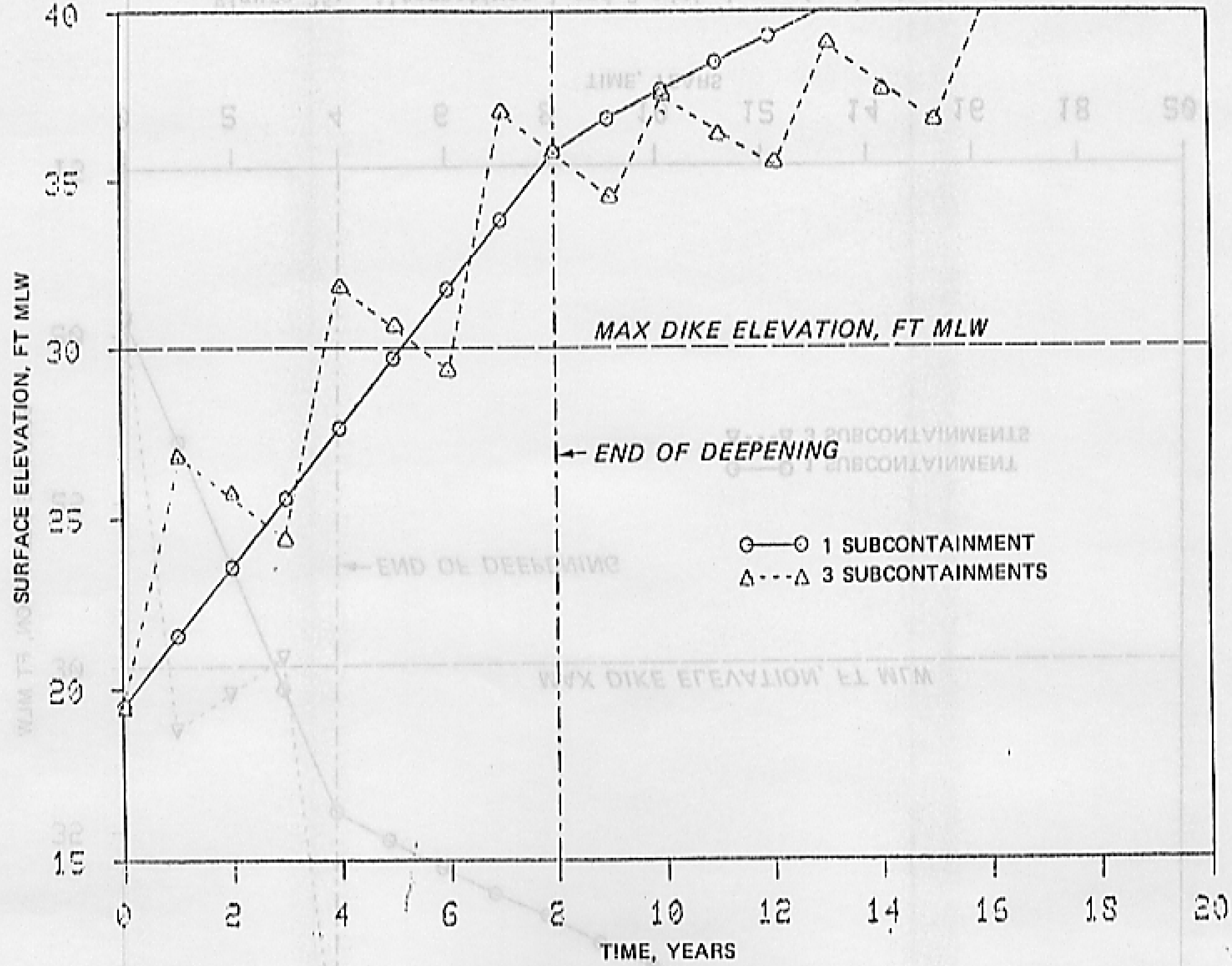

Figure 26: Alternatives 1 and 2 with deepening beginning in January 1986 for 8 years.

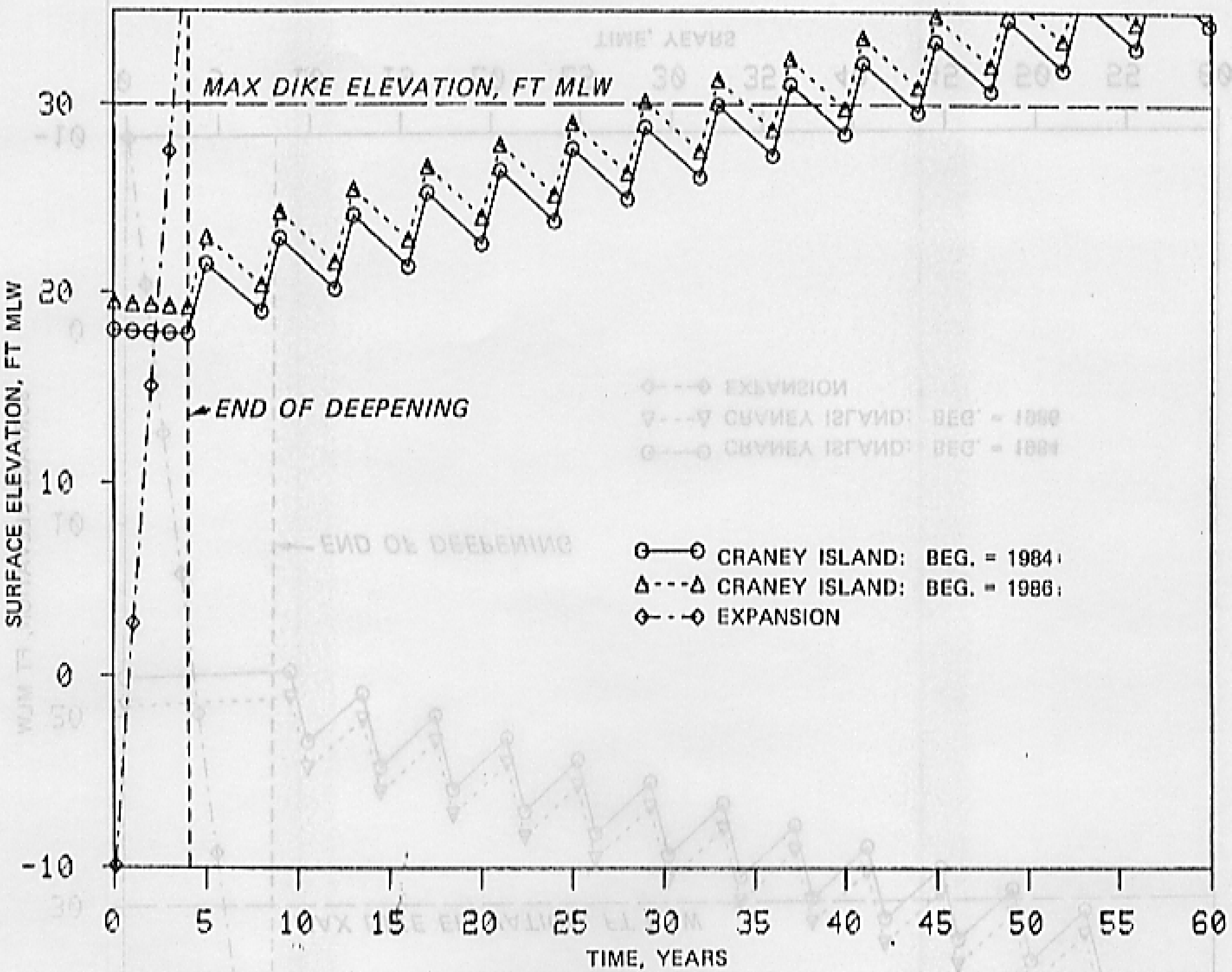

Figure 27: Alternative 3 with deepening lasting 4 years.

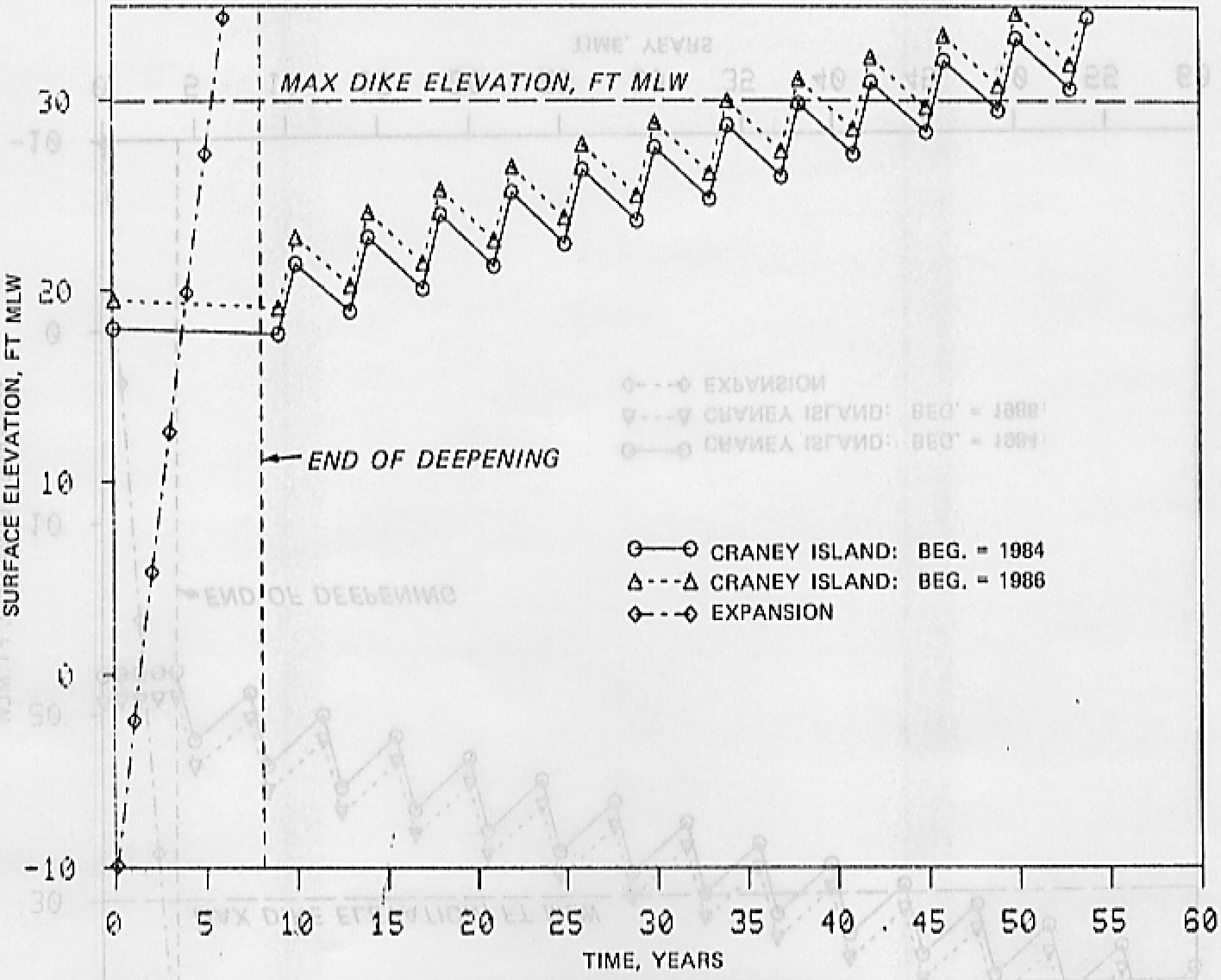

Figure 28: Alternative 3 with deepening lasting 8 years.

expansion will be exhausted before it could contain all of the material dredged during the deepening project. It can be extrapolated that an 850 acre expansion will be required to contain this volume with a final elevation less than +30 ft MLW. If this approach was used, the surface elevation projections in the CIMP are valid for the 3 subcontainment configuration which would now exist. Alternative 1, continue present mode of operation, would require dike construction on the exterior dikes only. The large ponded area required for this configuration will, however, complicate this construction. To contain the volume of new work material, the exterior dikes for the one subcontainment must be raised to contain material to +35 ft MLW. There would be no additional capacity for future maintenance dredging.

80. Alternative 2 is similar to the recommended construction plan in the CIMP. The rate of construction, however, must be accelerated to keep pace with the rate of filling which will be much faster than only maintenance dredging. The interior and exterior dikes would have to be capable of holding material up to a +30 ft elevation after only one year in one of the subcontainments. The second and third subcontainment would require this capability with one year additional time between the three (i.e. Subcontainment 1 - Year 1, Subcontainment 2 - Year 2, Subcontainment 3 - Year 3). It is probable that the entire deepening volume can be placed in Craney Island utilizing this configuration. This will require a short deepening period (approximately 4 years) and constant changing of the inflow point during the final year of filling. No additional storage capacity would remain for future maintenance dredging.

DOUBT IF THIS IS POSSIBLE

81. Alternative 3, which includes constructing a westward expansion, allows several years to complete the interior and exterior dike construction before any additional disposal to Craney Island. This should allow a dryer material to be used for dike construction. The expansion, however, would need to be rapidly constructed along the west dike of the existing containment area. This expansion would be used to contain most of the new work volume. At the end of the deepening project the storage volume in the expansion would be exhausted. Craney Island could then be used in an annual rotation for disposal of maintenance material in a three subcontainment configuration. After the

channel deepening is completed, over 20 years of maintenance dredging (at the current rate) should be required to fill Craney Island to +30 ft elevation. Figure 29 shows the surface projection for Craney Island in a 3 subcontainment configuration. The ordinate scale can be adjusted to the proper initial elevation to approximate any starting date.

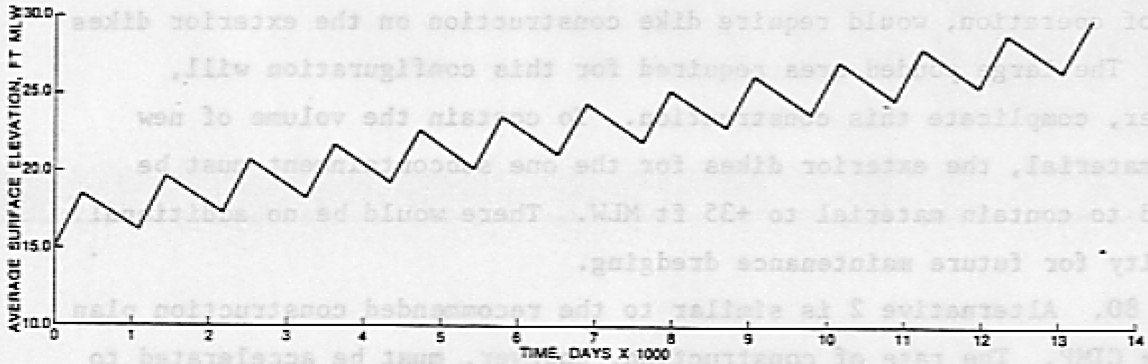

Figure 29. Extended storage capacity projection for three-subcontainment configuration with surface water management and active dewatering (from CIMP).

DOUBT IF THIS IS POSSIBLE

82. Other possible disposal schemes are shown in Figures 30 and 31. These show the effect of filling the expansion to the level of Craney Island, then beginning the annual rotation between the four subcontainments. In this manner, the full potential of dewatering and desiccation could be used to increase the storage volume. This optimal scheme, however, will require a rapid dike raising to keep ahead of the filling operation. The construction after this will also be demanding. Craney Island would need to be subdivided and the expansion capable of holding material to a height equivalent to the Craney Island surface within a few years after the deepening begins. The projection shown in Figures 30 and 31 can be adjusted along the ordinate scale and the abscissa scale to reflect any situation. The advantages of this scheme, however, can be seen in Figure 30, which shows a life of the disposal areas of over 20 years after the deepening is completed.

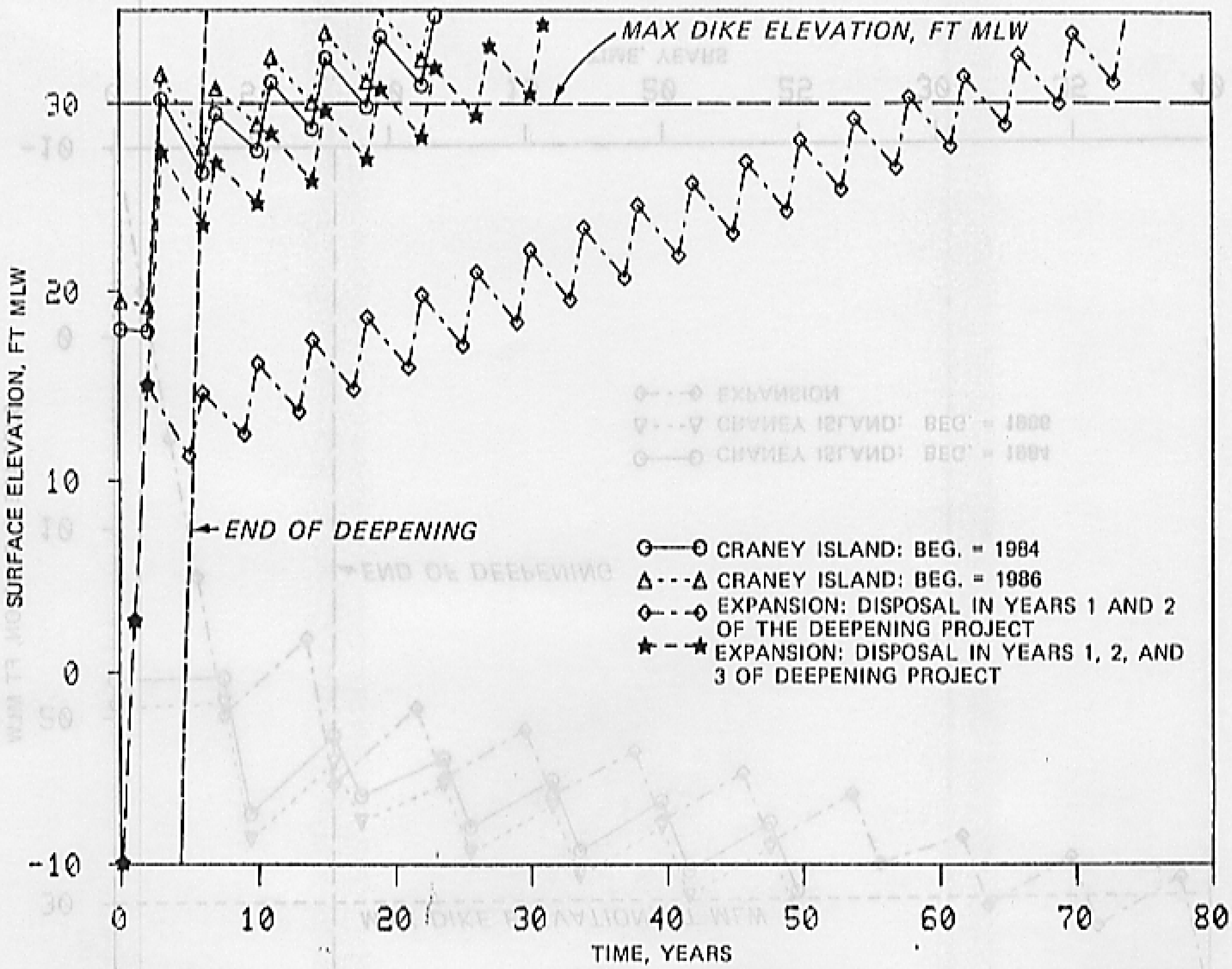

Figure 30: Disposal sequencing scheme for deepening project lasting for 4 years.

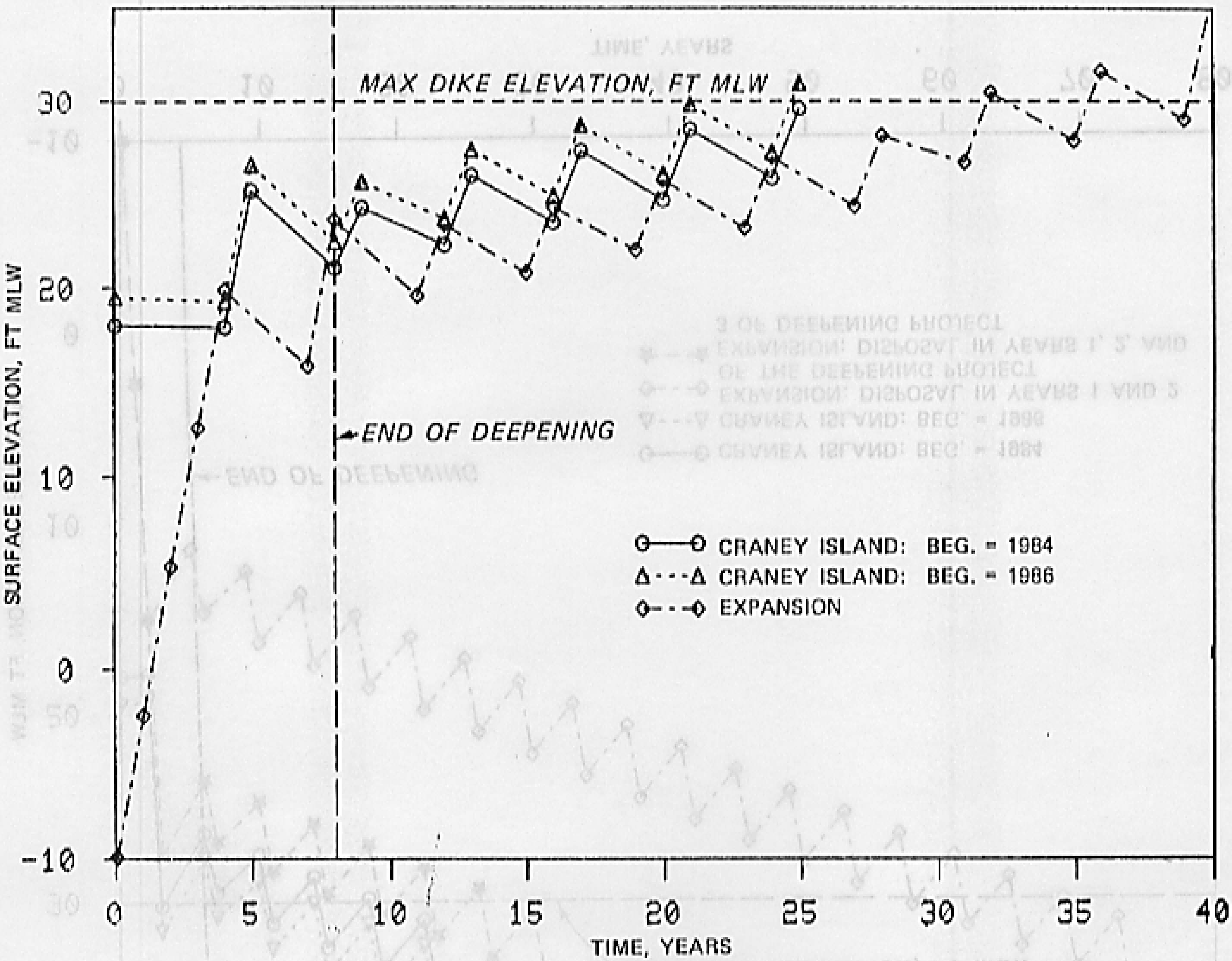

Figure 31: Disposal sequencing scheme for deepening project lasting for 8 years.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

83. From the data and facts presented in the preceding discussion the following general conclusions can be drawn:

- a. The allowable inflow during the filling operation should be limited to 245 cfs, due to weir constraints. This is much larger than any normal inflow which would occur and should be sufficient to handle any additional effluent from precipitation.
- b. The large volumes of new work material will quickly exhaust the remaining storage capacity of Craney Island in its present configuration.
- c. Close coordination between dredging and construction is required for all alternatives. This aspect is especially critical for Alternative 2.

84. Assuming that the maximum allowable surface elevation for Craney Island and any westward expansion is +30 ft MLW, the following specific conclusions can be drawn:

- a. Alternative 1 will exhaust all available storage capacity after 5 years (before the deepening is completed).
- b. Alternative 2 allows the entire deepening volume to be placed into Craney Island. Additional storage capacity at other sites will be required for maintenance dredging after the deepening is completed.
- c. An expansion with a surface area of 850 acres capable of being filled to +30 ft MLW will hold the deepening and maintenance material during the deepening project. This would leave the remaining volume of Craney Island for future maintenance dredging.
- d. A scheme of disposing only part of the material into an expansion and the remainder into Craney Island (as shown in Figures 30 and 31) will also retain a large storage volume for future maintenance dredging.

Recommendations

85. The following recommendations are made based on the preceding discussion and conclusions:

- a. An additional subcontainment should be constructed along the west dike to accommodate the new work material. This subcontainment should have a surface area of 750 acres and a length-to-width ratio of 2 (see Appendix B).

b. The new work and maintenance sediment dredged during the deepening project should be placed in this subcontainment until it reaches an elevation equivalent to Craney Island. Then an annual rotation system using four subcontainments should be utilized.

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APPENDIX A: LABORATORY SEDIMENTATION TEST DATA

1. This appendix presents test results for a series of column sedimentation tests performed on sediment samples taken from locations within the Norfolk harbor channel (see Figure 1). The tests were performed in 8-in.-diam settling columns according to the following procedures:

- a. Slurries of sediment and water were prepared at varying concentrations (shown on individual test results) and placed in the settling column.
- b. Depth of solid-liquid interface was recorded with respect to time.
- c. Readings were taken until the maximum point of curvature of depth to interface versus time plot was defined.

2. The slope of the straightline portion defines the zone settling velocity for each respective test (Figures A1-A8). Results of these tests were used to develop relationships of zone settling velocity versus concentration (see Figure 14).

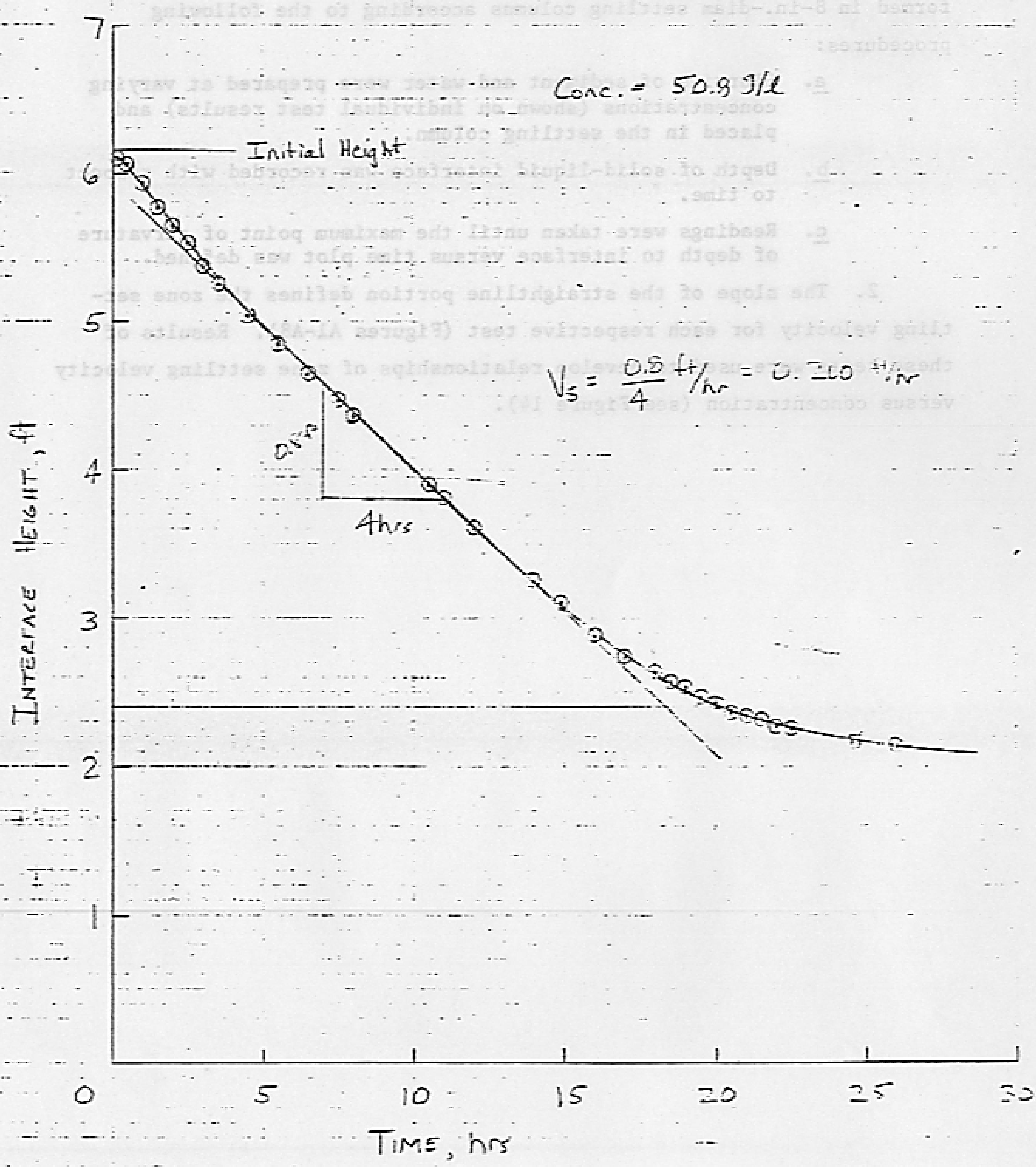

Conc. = 50.8 g/l
Initial Height
0.5 ft
4 hrs
$V_s = \frac{0.5}{4}$ ft/hr = 0.120 ft/hr
Interface Height, ft
Time, hrs
0
5
10
15
20
25
30
1
2
3
4
5
6
7

Figure A1

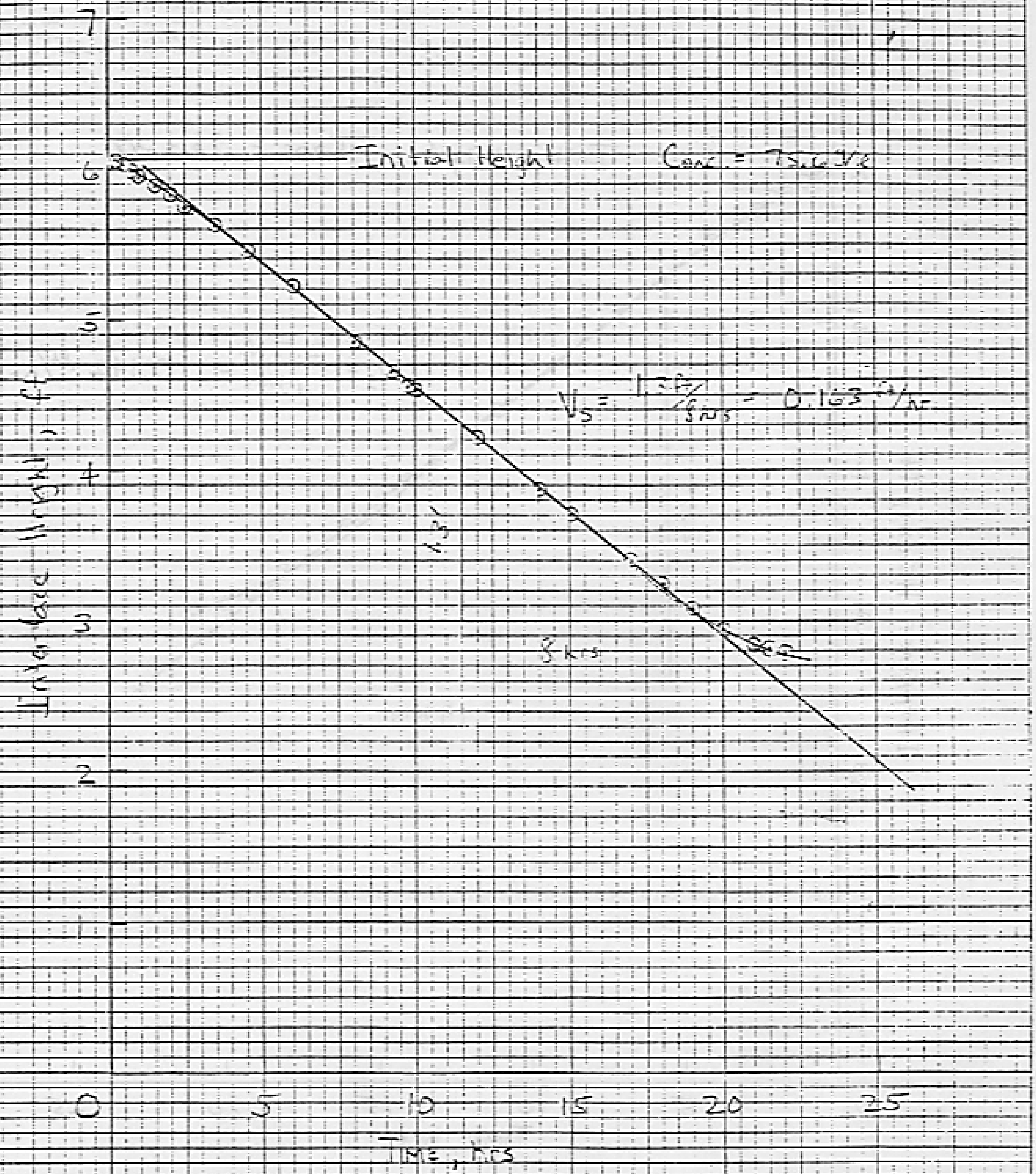


Figure A2

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
DIETZGEN CORPORATION
MADE IN U.S.A.

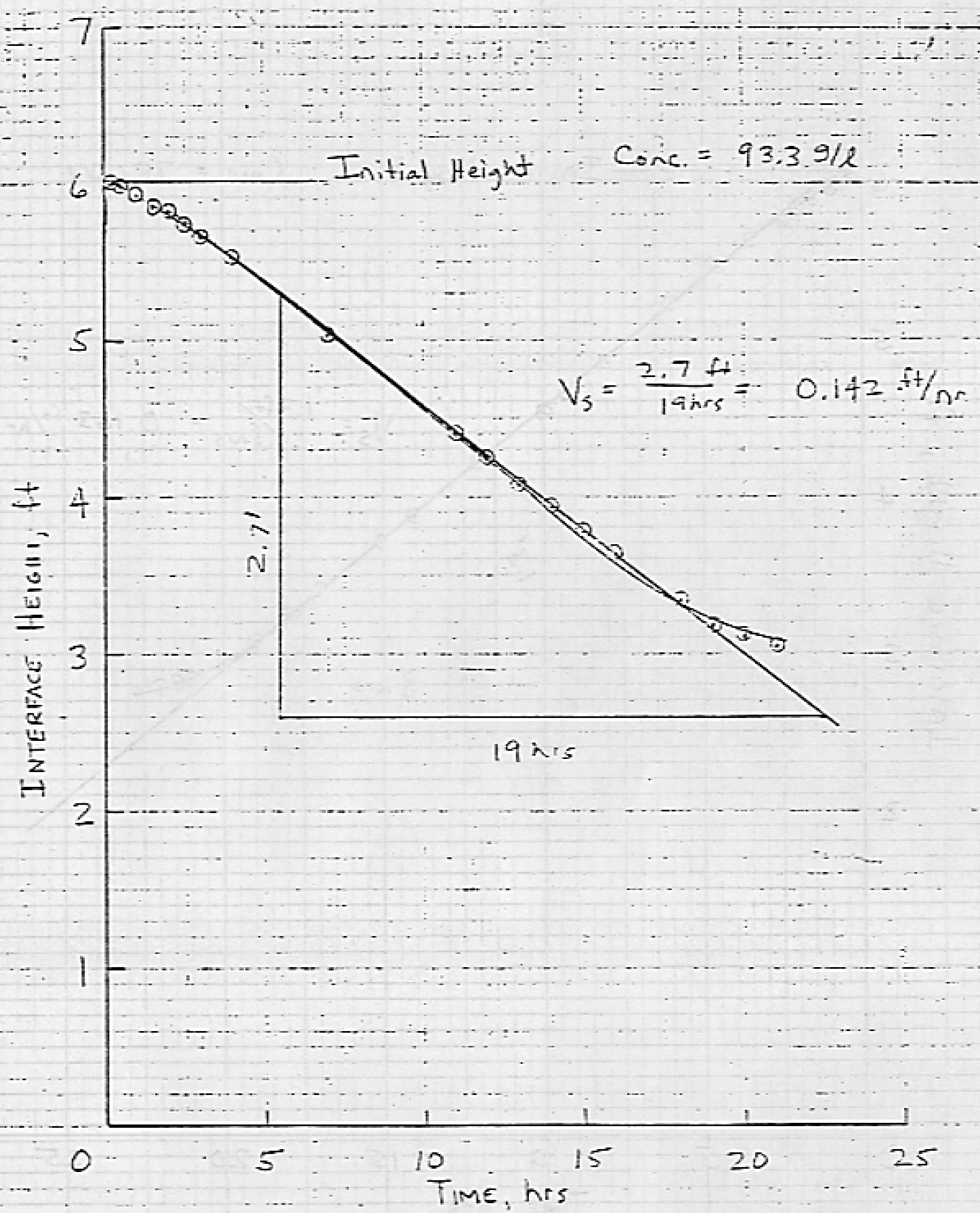
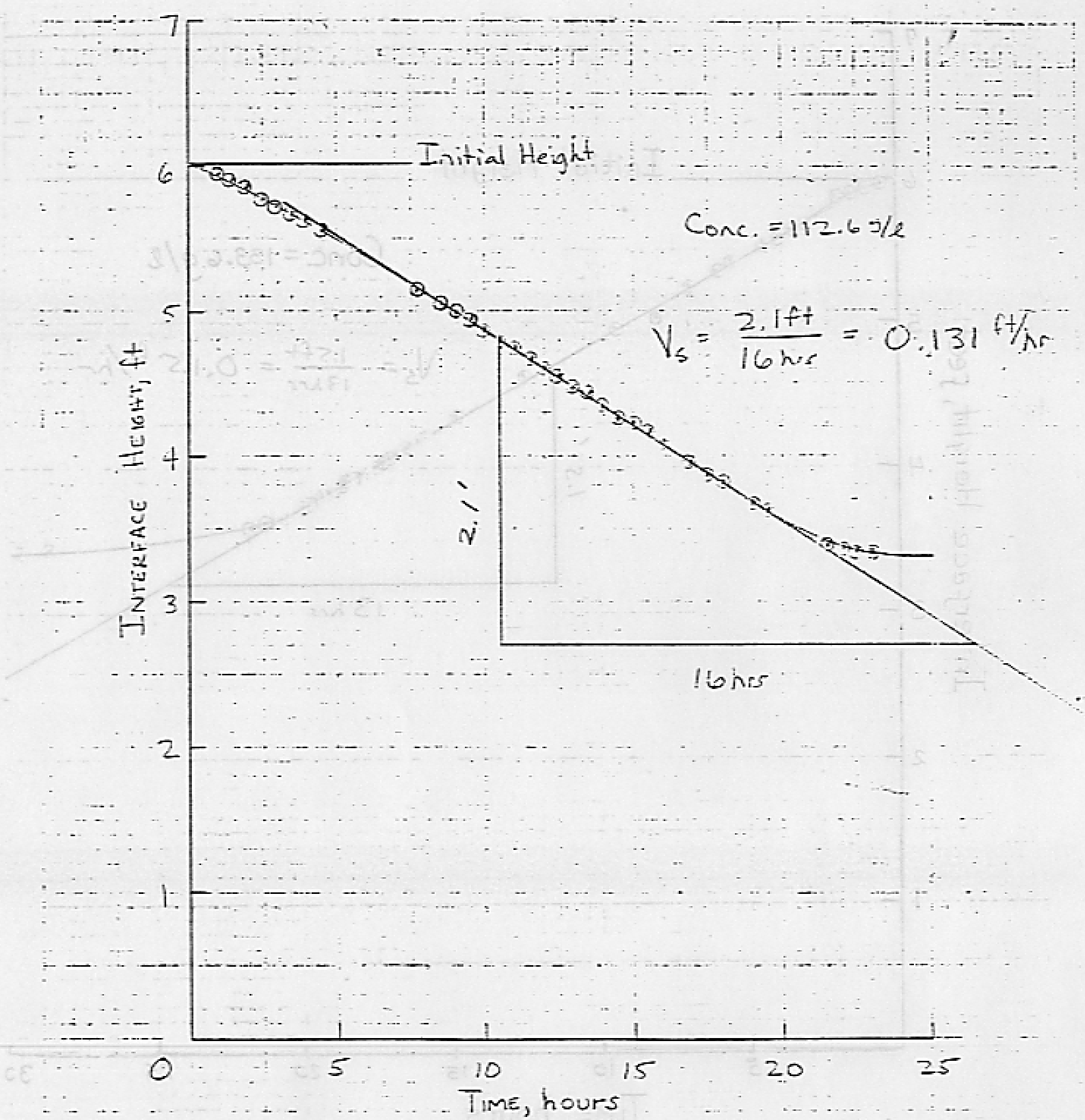

Initial Height
Conc. = 93.3 g/l
$V_s = \frac{2.7\ ft}{19\ hrs} = 0.142\ ft/hr$
2.7'
19 hrs
7
6
5
4
3
2
1
0
5
10
15
20
25
INTERFACE HEIGHT, ft
TIME, hrs

Figure A3



Initial Height
Conc. = 112.6 g/l
$V_s = \frac{2.1 ft}{16 hr} = 0.131$ ft/hr
2.1'
16 hrs
Interface Height, ft
Time, hours
0
5
10
15
20
25
1
2
3
4
5
6
7

Figure A4

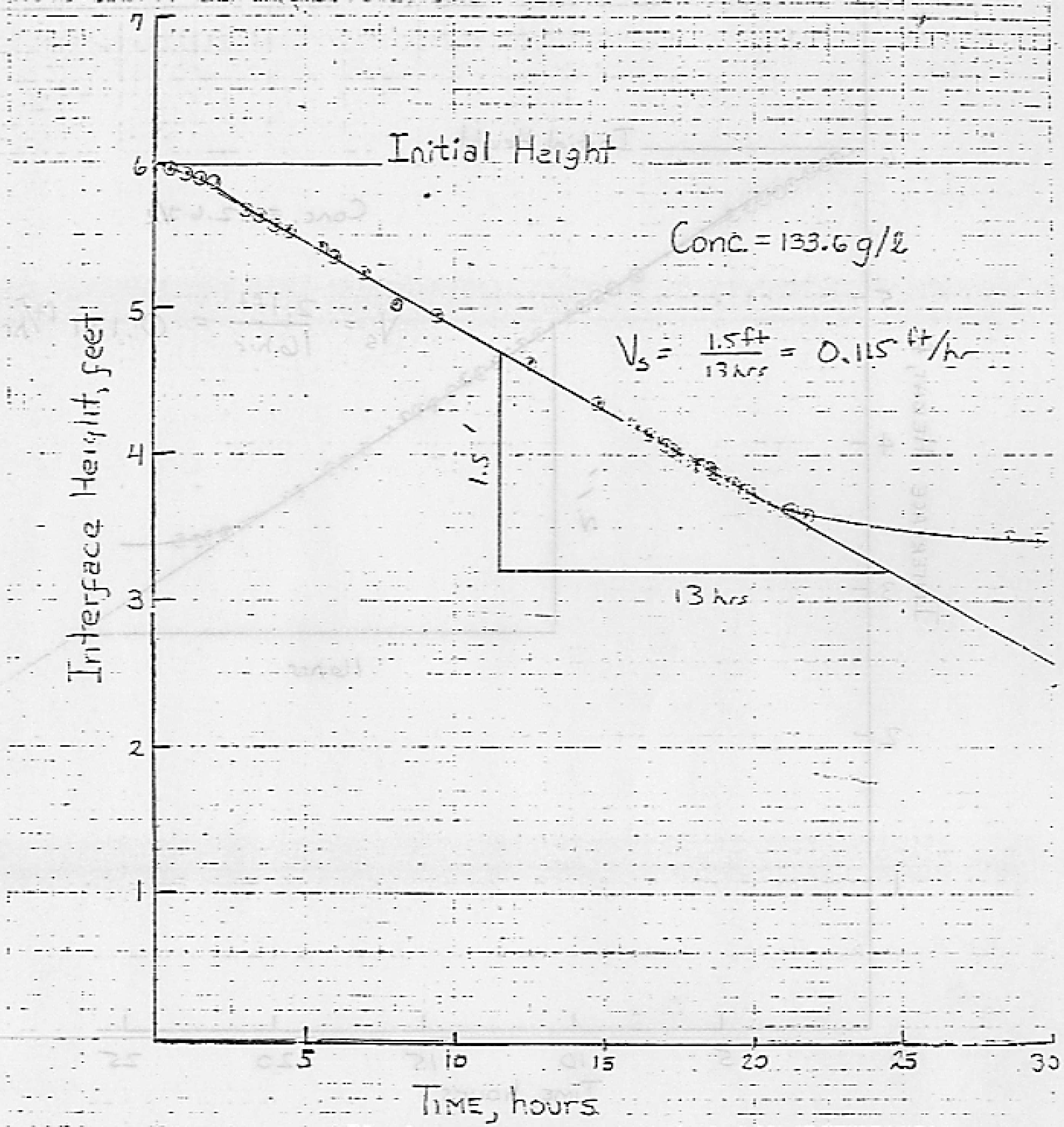
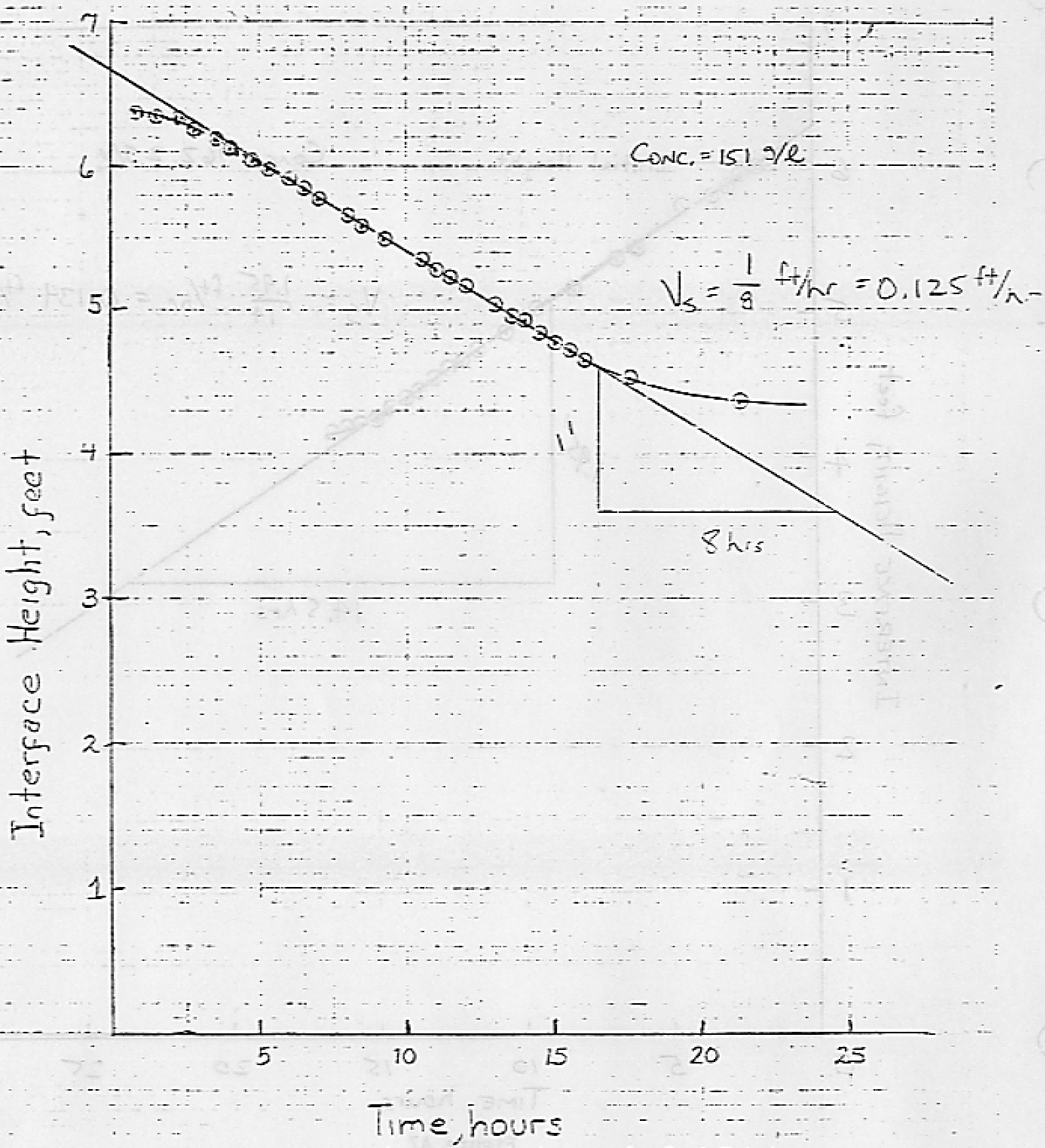
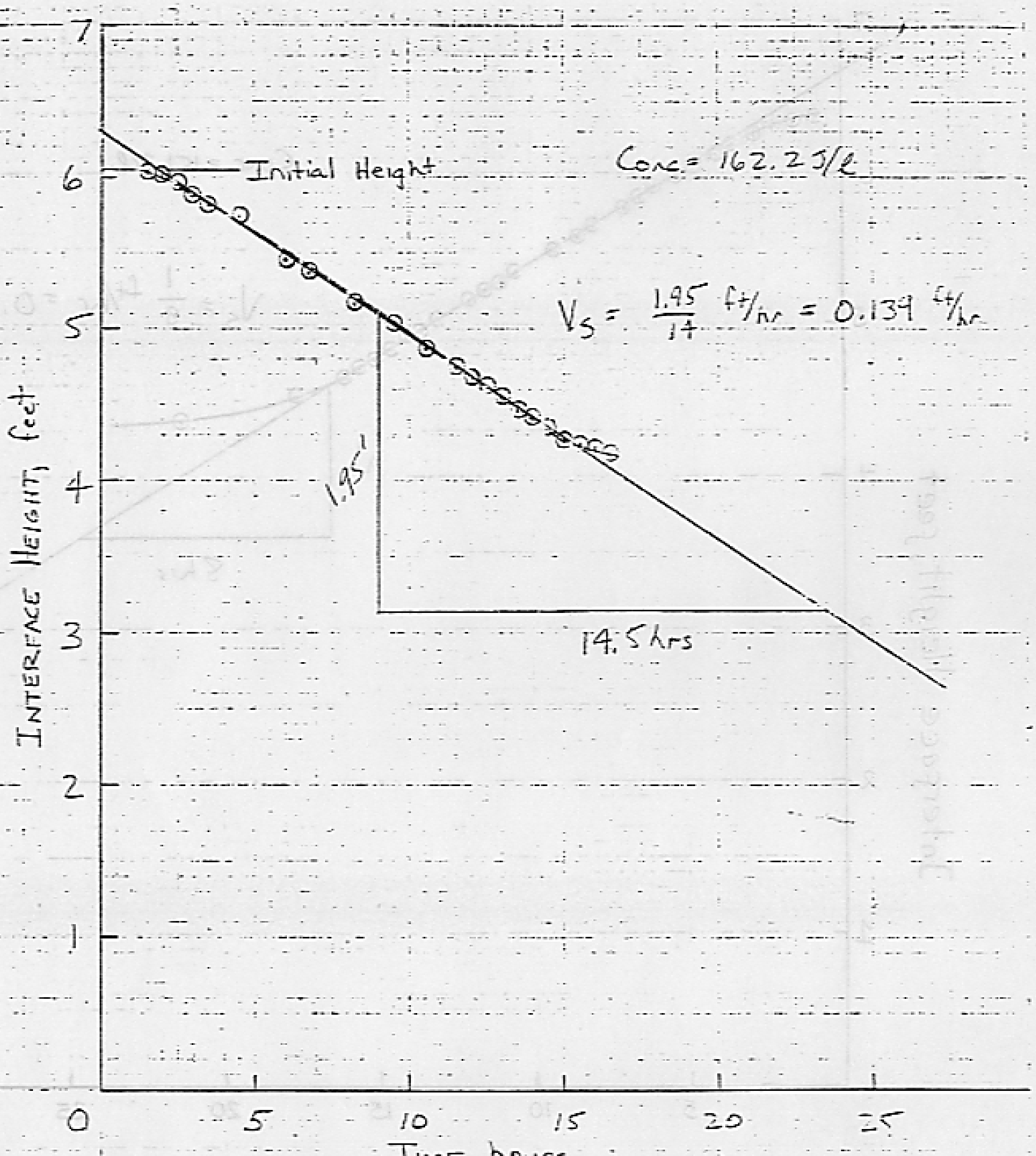

Initial Height
Conc. = 133.6 g/l
$V_s = \frac{1.5 ft}{13 hrs} = 0.115 ft/hr$
1.5'
13 hrs
Interface Height, feet
Time, hours
7
6
5
4
3
2
1
5
10
15
20
25
30

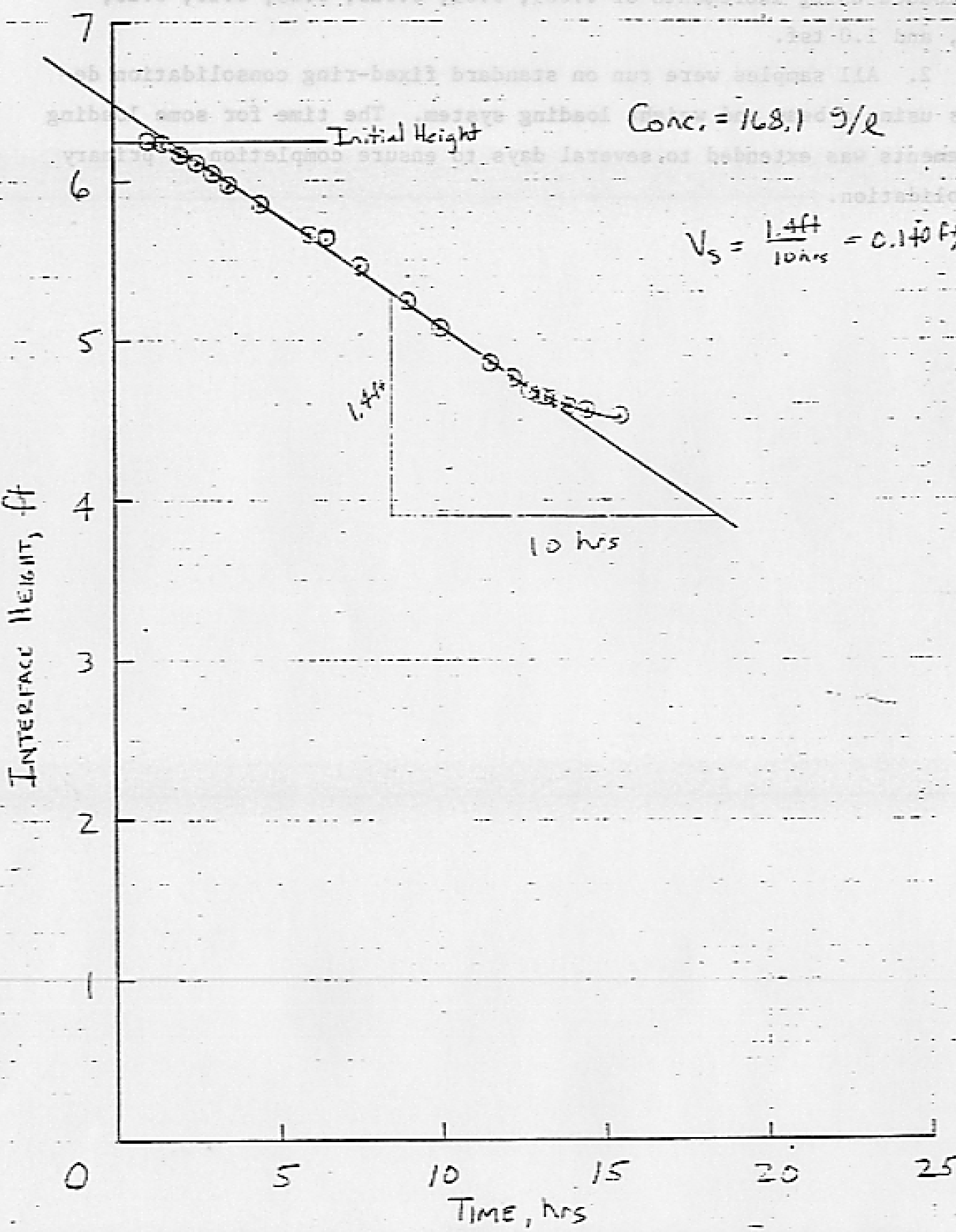
Figure A5



7
6
5
4
3
2
1
Interface Height, feet
Conc. = 151 g/l
$V_s = \frac{1}{8}$ ft/hr = 0.125 ft/hr
1'
8 hrs
5
10
15
20
25
Time, hours

Figure A6


Initial Height
Conc = 162.2 g/l
$V_s = \frac{1.95}{14}$ ft/hr = 0.139 ft/hr
1.95'
14.5 hrs
Interface Height, feet
Time, hours
0
5
10
15
20
25
1
2
3
4
5
6
7
Figure A7



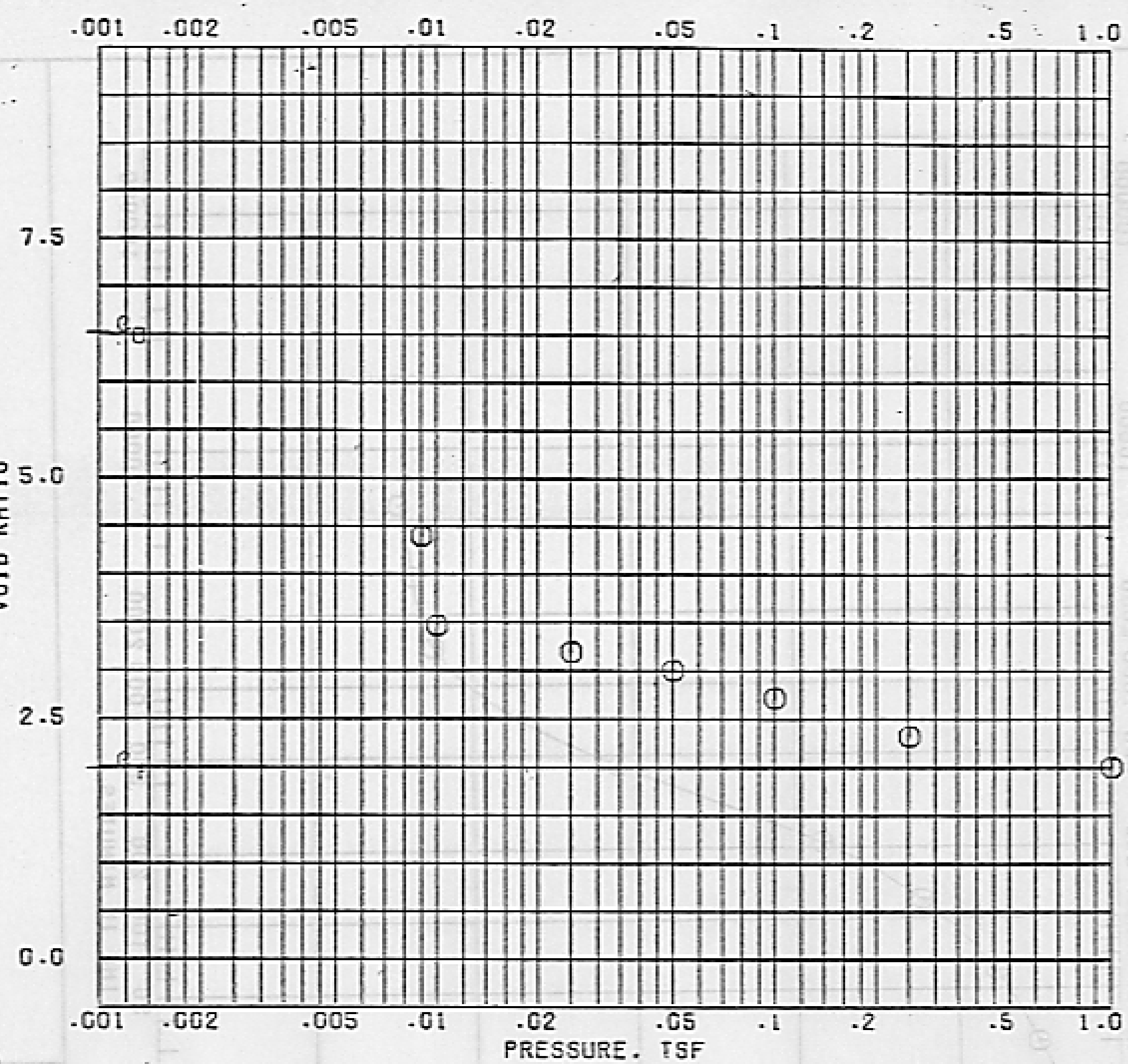
Initial Height
Conc. = 168.1 g/l
$V_s = \frac{1.4 ft}{10 hrs} = 0.140$ ft/hr
1.4 ft
10 hrs
Interface Height, ft
Time, hrs
0
1
2
3
4
5
6
7
5
10
15
20
25

Figure A8

APPENDIX B: LABORATORY CONSOLIDATION TEST DATA

1. This appendix presents detailed test results (Figures B1-B8) for consolidation tests performed on sediment samples taken from locations shown in Figure 1. These samples were run in a remolded condition and loaded using increments of 0.009, 0.01, 0.025, 0.05, 0.10, 0.25, 0.50, and 1.0 tsf.

2. All samples were run on standard fixed-ring consolidation devices using a beam and weight loading system. The time for some loading increments was extended to several days to ensure completion of primary consolidation.



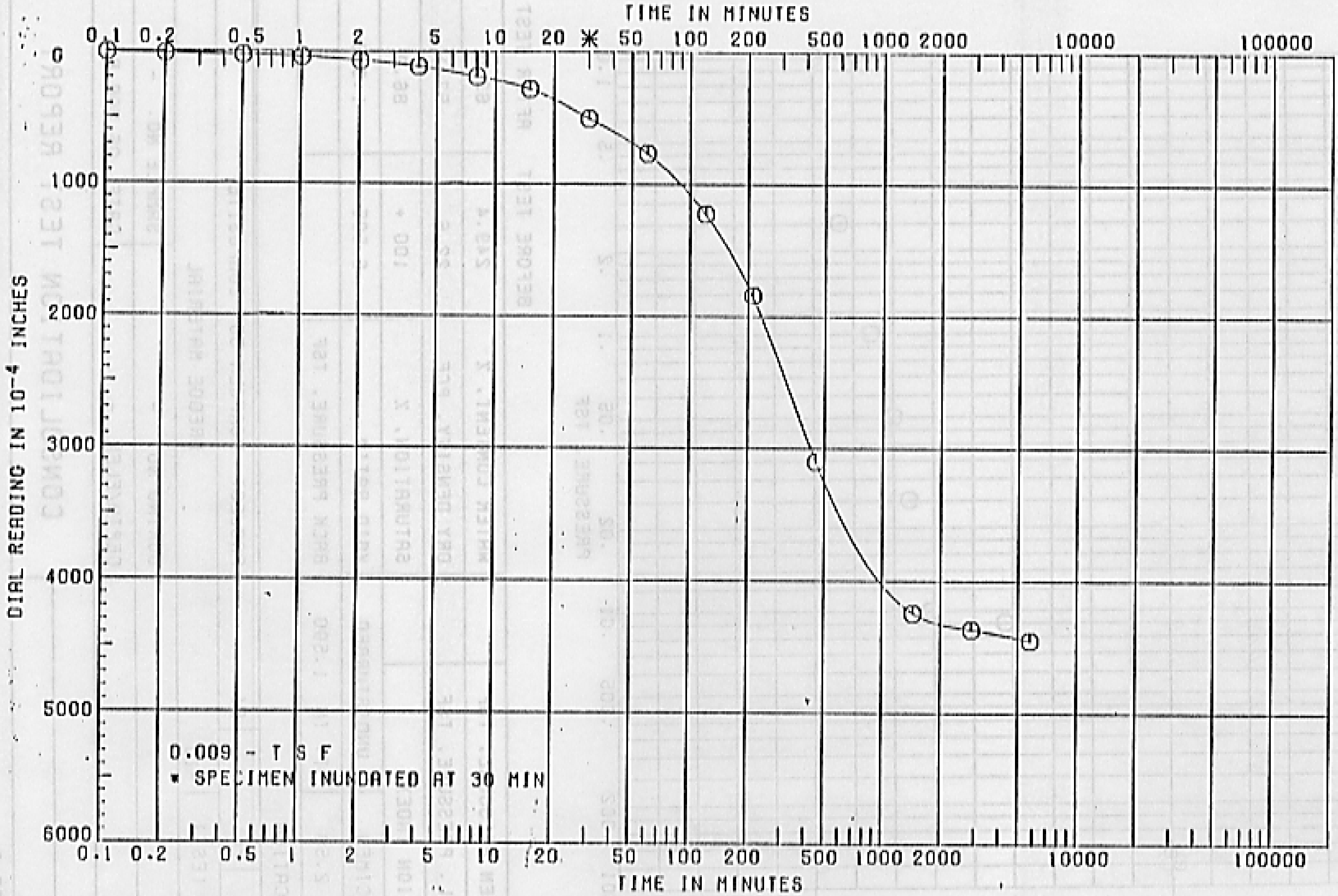
			BEFORE TEST	AFTER TEST
OVERBURDEN PRESSURE, TSF		WATER CONTENT, %	249.4	63.0
PRECONSOL. PRESSURE, TSF		DRY DENSITY, PCF	22.6	57.1
COMPRESSION INDEX		SATURATION, %	100 +	86.9
TYPE SPECIMEN	UNDISTURBED	VOID RATIO	6.505	1.972
DIA. IN 2.50	HT. IN 1.500	BACK PRESSURE, TSF		

CLASSIFICATION			
LL	PL	PI	PROJECT NORFOLK 50' COMPOSITE
GS 2.72 (EST)	D_{10}		DREDGE MATERIAL
REMARKS			BORING NO. - / SAMPLE NO. -
			DEPTH/ELEV - / DATE 05 MAR 82

CONSOLIDATION TEST REPORT

SHEET 1 OF 8

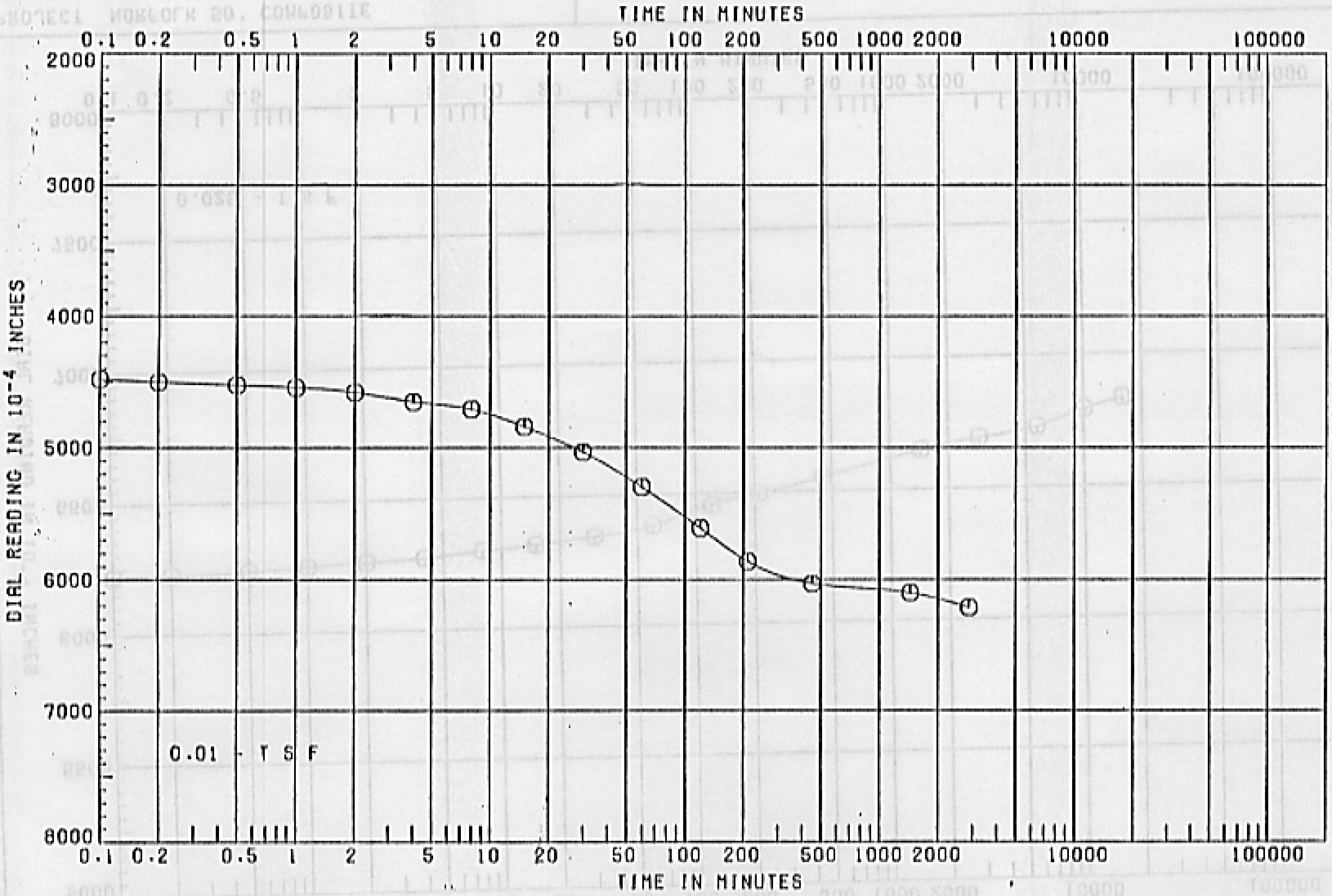
Figure B1



PROJECT	NORFOLK 50' COMPOSITE		CONSOLIDATION TEST
	DREDGE MATERIAL		TIME CURVES
BORING -		SAMPLE NO. -	
DEPTH/ELEV -		DATE 05 MAR 82	

SHEET [illegible] OF 8

Figure B2



PROJECT NORFOLK 50' COMPOSITE	
DREDGE MATERIAL	
BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 05 MAR 82

CONSOLIDATION TEST

TIME CURVES

SHEET 1 OF 8

Figure B3

B4

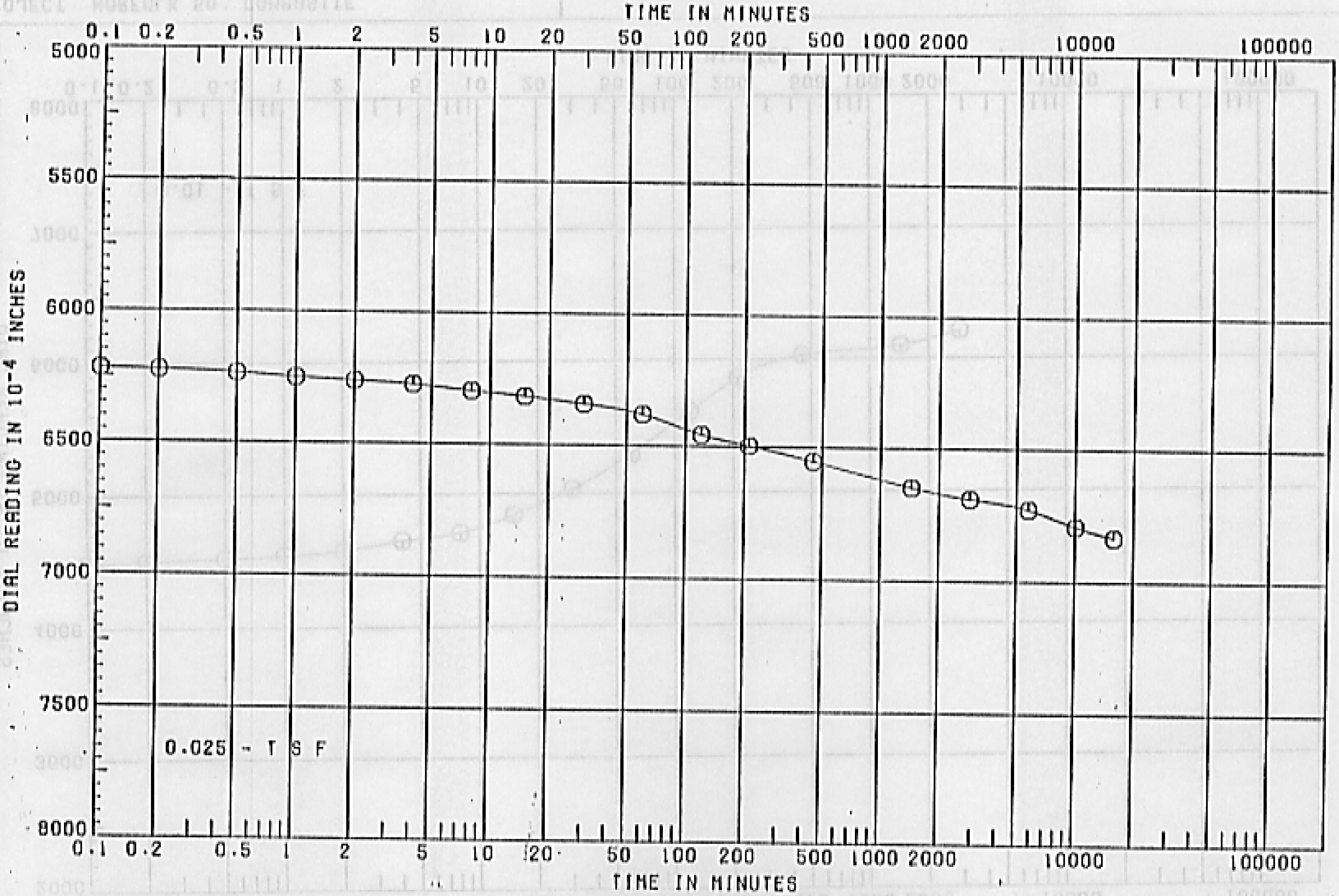


Figure B4

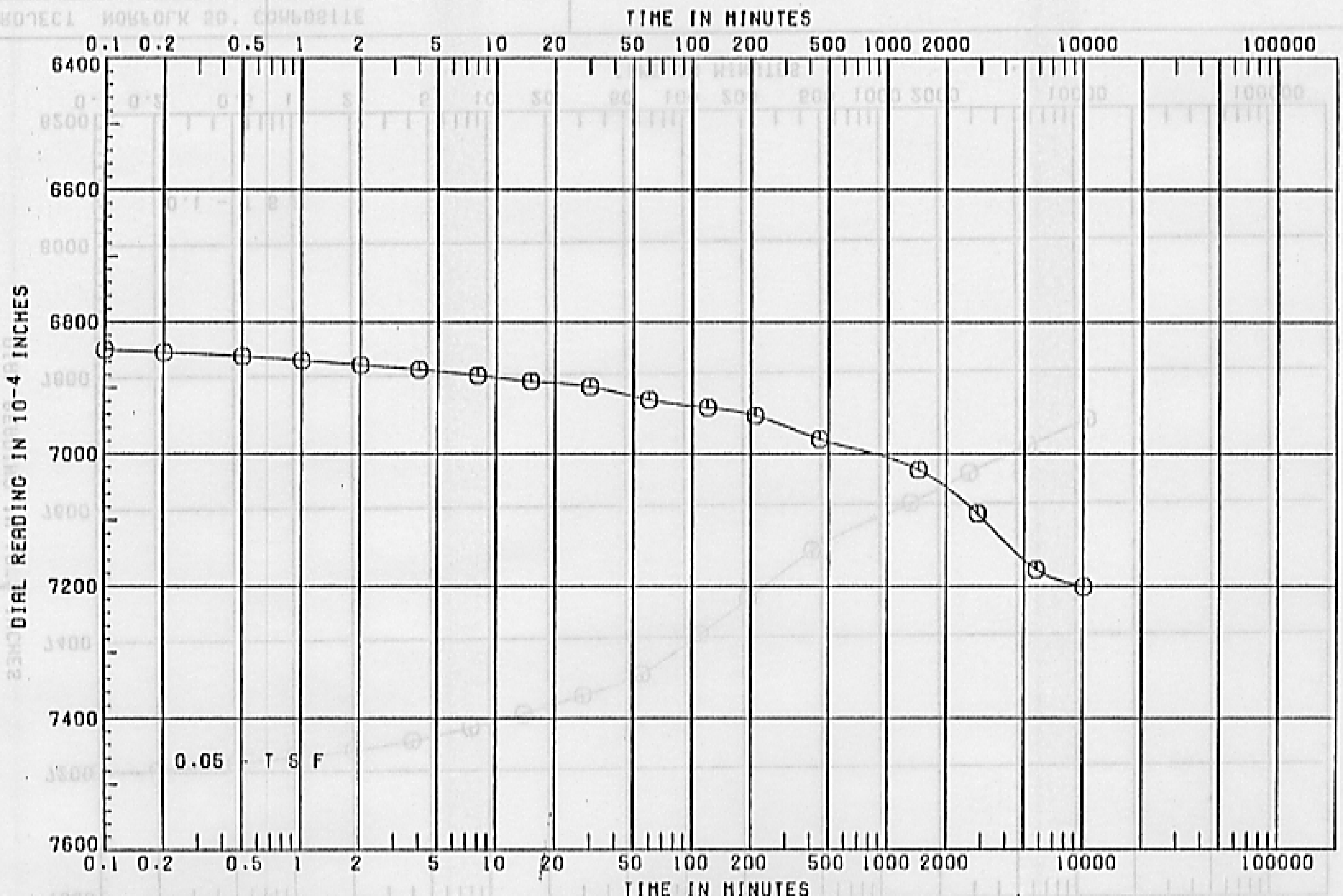
B5

PROJECT NORFOLK 50' COMPOSITE	
DREDGE MATERIAL	
BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 05 MAR 82

CONSOLIDATION TEST

TIME CURVES

SHEET 1 OF 8



PROJECT NORFOLK 50' COMPOSITE	
DREDGE MATERIAL	
BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 05 MAR 82

CONSOLIDATION TEST
TIME CURVES

SHEET 8 OF 8

Figure B5

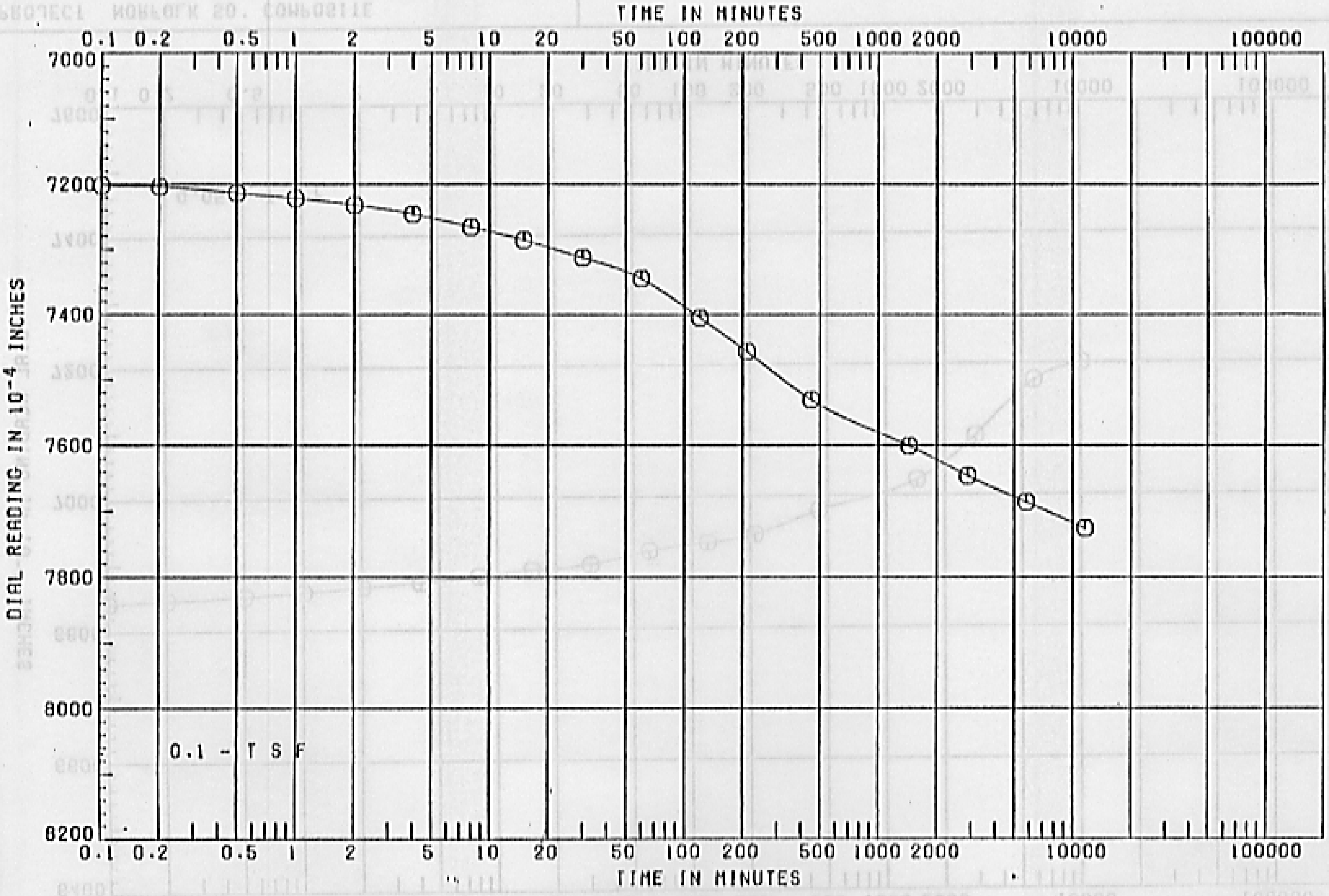


Figure B6

PROJECT NORFOLK 50' COMPOSITE	
DREDGE MATERIAL	
BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 05 MAR 82

SHEET [illegible] OF 8

CONSOLIDATION TEST

TIME CURVES

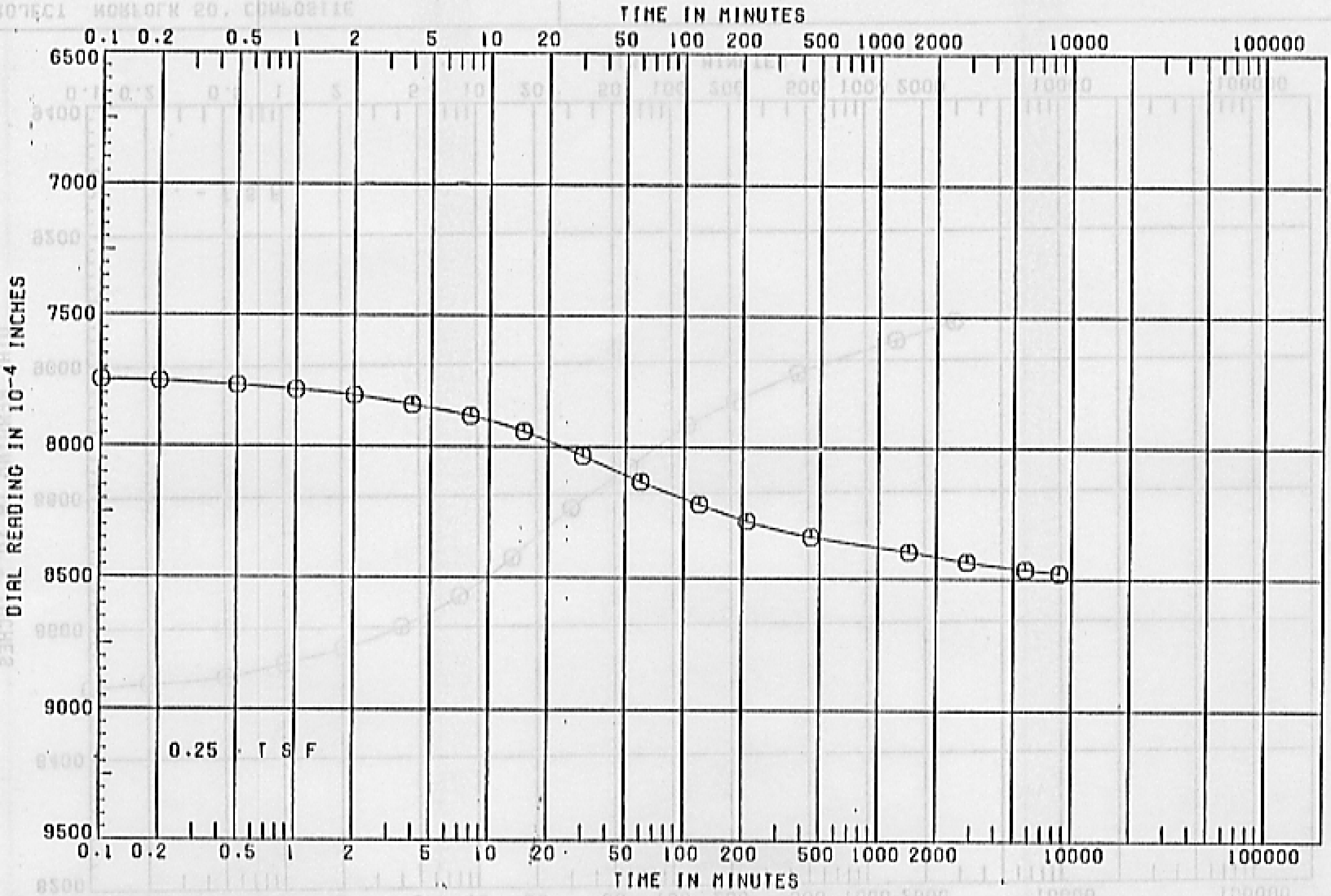


Figure B7

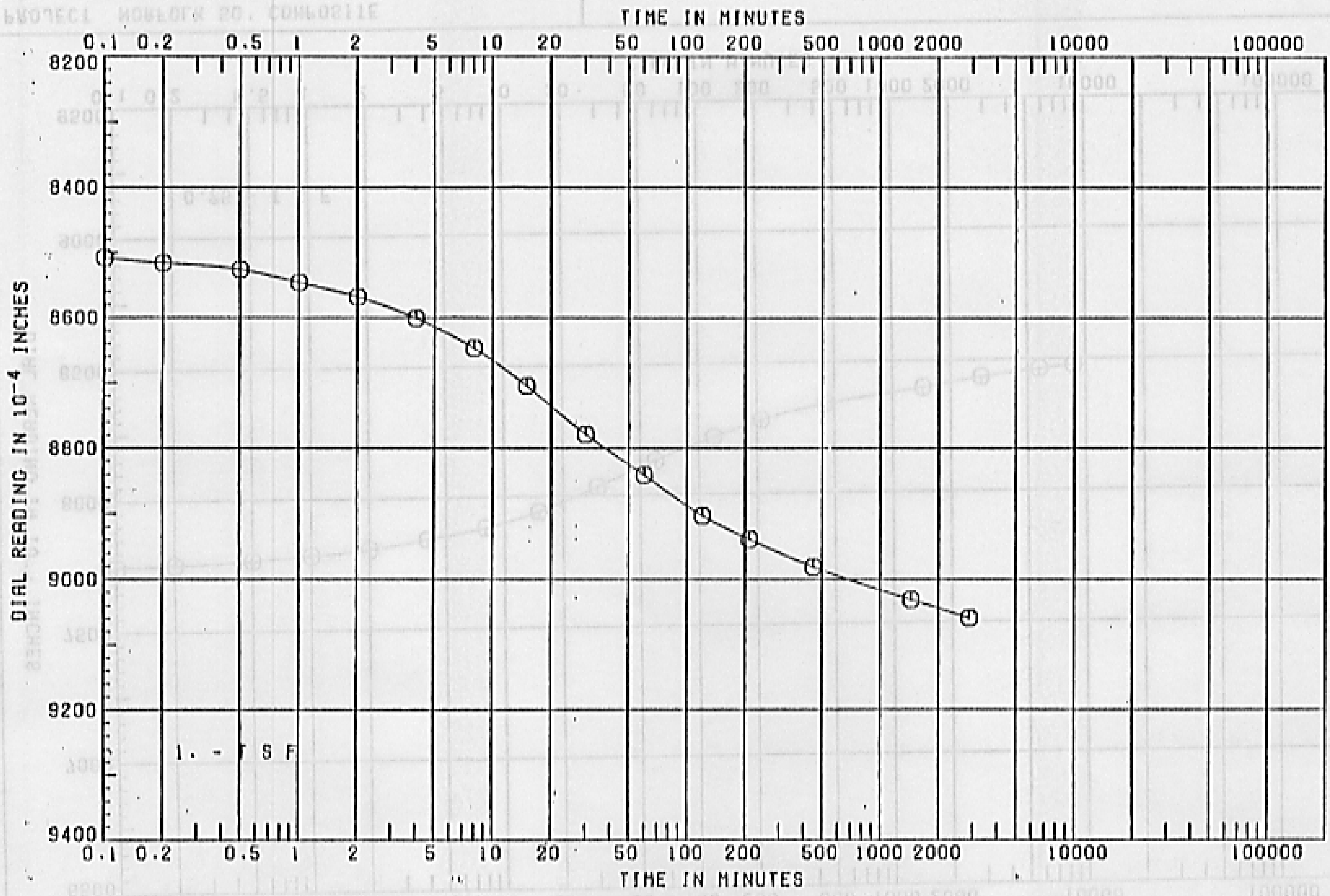
B8

PROJECT NORFOLK 50' COMPOSITE	
DREDGE MATERIAL	
BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 05 MAR 82

CONSOLIDATION TEST

TIME CURVES

SHEET [illegible] OF 8



PROJECT NORFOLK 50' COMPOSITE	
DREDGE MATERIAL	
BORING -	SAMPLE NO. -
DEPTH/ELEV -	DATE 05 MAR 82
SHEET [illegible] OF 8	

CONSOLIDATION TEST

TIME CURVES

Figure B8

APPENDIX C: RECOMMENDATIONS FOR CONSTRUCTION OF AN EXPANSION TO CRANEY ISLAND

1. This appendix presents recommendations for constructing an expansion to Craney Island as required for alternative 3. Reasons and background for the recommendations are presented where appropriate. The following recommendations are made:

<u>a.</u> <u>The expansion should be built along the western dike of Craney Island.</u> An expansion along either the northern or eastern dike may result in possible slope stability problems for the navigation channel.

<u>b.</u> <u>The expanded surface area should be equivalent to that of one of the sub-containments (750 acres).</u> This would provide adequate surface area for the large inflow which should occur during the channel deepening.

<u>c.</u> <u>The length-to-width ratio of the expansion should be 2:1 to provide the largest surface area with the lowest corresponding length of dike construction.</u> Because one side of the expansion already exists, the length of dike which must be constructed, P , is

$$P = L + 2W$$

where

P = total perimeter dike length to be constructed, ft
L = length of longer side of perimeter dike, ft
W = length of shorter side of perimeter dike, ft

It can be easily shown from this relationship that the minimum P for a given area is where

$$L = 2W$$

$L^2/2 = 43560(750)$
$= 8083.3$ OK

For a surface area of 750 acres these dimensions are 4040 ft by 8080 ft. Figure C1 shows the approximate location and scaled dimensions for this size area.

<u>d.</u> <u>The weirs should be located in the south corners of the expansion.</u> The same weir lengths (75' each) as suggested in the CIMP should be suitable if the flows are less than 250 cfs. However, if larger flows are anticipated during the channel deepening, the weir lengths should be increased appropriately. Because of the weir locations, all inflows should be located at the north end of the expansion.

<u>e.</u> <u>The effluent pipes from the weirs in Craney Island should be extended to by-pass the expansion.</u>

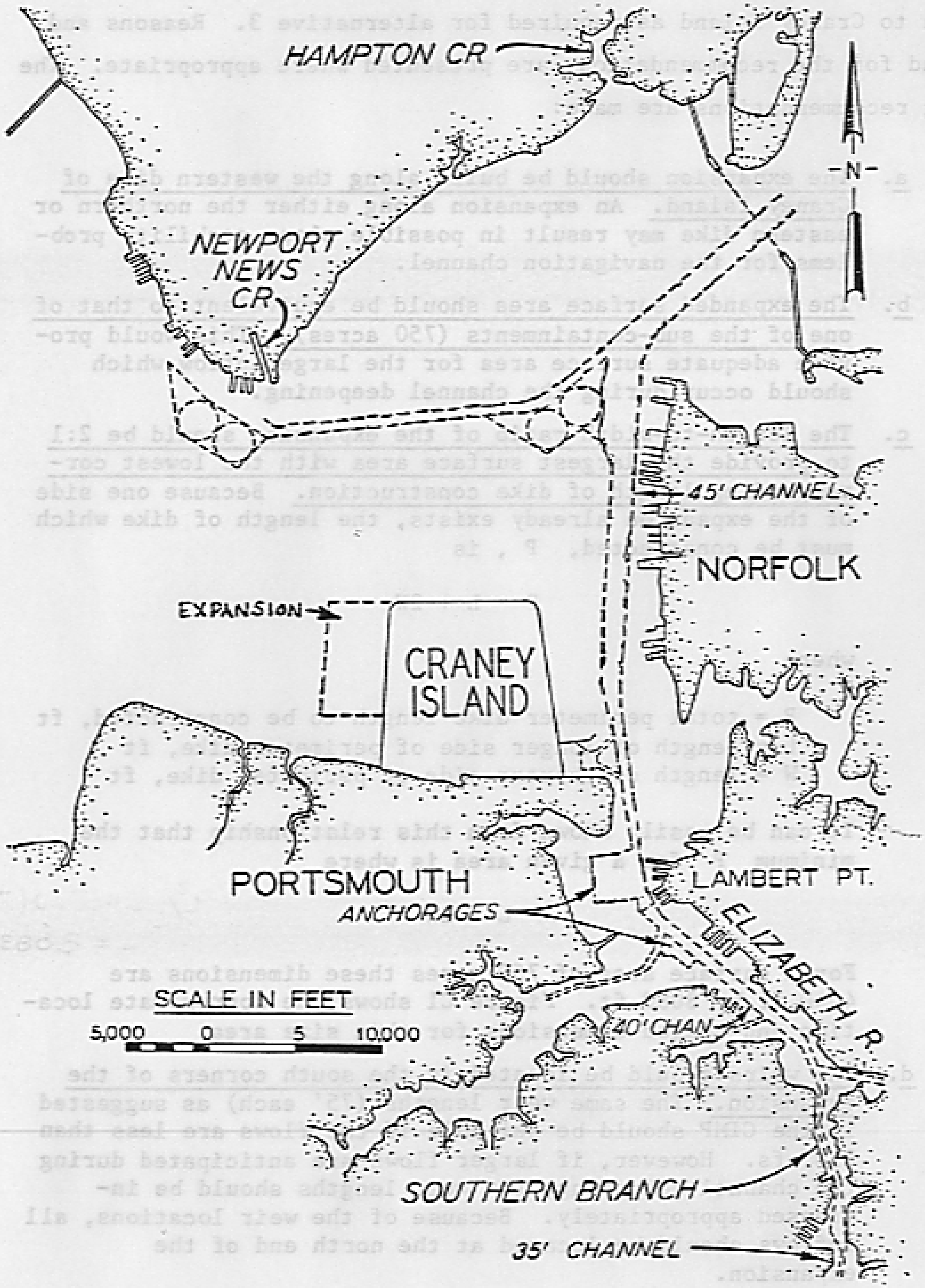


Figure C1: Suggested location and approximate scaled dimensions for expansion.